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HARVARD COLLEGE
May 27
Fred W. Taylor

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PREFACE

THE purpose of this little book will be fulfilled if by this means the users of oil as fuel, both present and prospective, are enabled to secure a more comprehensive idea of the advantages of this fuel. It is hoped that sufficient data of value may be found herein to warrant its inclusion in the library of the recipient as a handy reference.

One of the Five Refineries of the Texas Company, Port Arthur, Texas

OIL FUEL

NOT many years ago the use of petroleum as a fuel for commercial purposes was a luxury not to be considered. The product of the Pennsylvania, West Virginia and Ohio fields was considered too valuable to be used for any but refinery purposes, and, moreover, it was not adapted for fuel in its crude stages, on account of its light, volatile nature.

With the opening up of the California, Oklahoma, and Gulf Coast oil fields, of Texas, Louisiana and Mexico—yielding a heavier product in enormous quantities, and one admirably adapted for boiler use—these conditions were changed, the consequence being a demand for oil, with all its advantages over any other commercial fuel except natural gas.

The Texas Company was early in this oil fuel field, organizing in the year 1902. Since that time, by fair dealing and reliability, in connection with constant attention to the demands of its customers, its present large oil fuel trade has been developed.

Ocean terminals distributed along the Atlantic and Gulf Coast from Maine to Mexico, loading racks at such terminals, as well as adjacent to all the principal business centers of Texas, Louisiana and Oklahoma; place the Texas Company in a position to make deliveries on short notice. It has been, and always will be, the policy of this Company to protect its customers in the matter of quality and delivery.

A FEW OF THE ADVANTAGES IN THE USE OF OIL AS FUEL

Stationary Plants:

1. General cleanliness.
2. High boiler and furnace efficiency.
3. Ability to carry overloads and meet, almost instantly, wide ranges in load.
4. Total absence of smoke.
5. Uniform draft and air supply, giving minimum variation in furnace temperature.
6. No loss when stored indefinitely.
7. Storage in any convenient place.
8. Low cost of handling.

For Marine Purposes:

1. Quick steaming.
2. Quick bunkering from shore or by lighter—in rain or shine—day or night—with complete absence of dirt and dust in transferring from one ship to another.
3. Utilizes storage space on board ship which could not be used for coal.
4. Increased steaming radius for a given storage volume or dead weight.
5. Greater uniformity of fuel.
6. Storage in any part of the world for long periods of time without deterioration.
7. No spontaneous combustion.
8. Decreased boiler room force and the hardships of the stoker room removed.
9. Absence of dust, ashes in engine room and the consequent reduction of wear of the working parts.

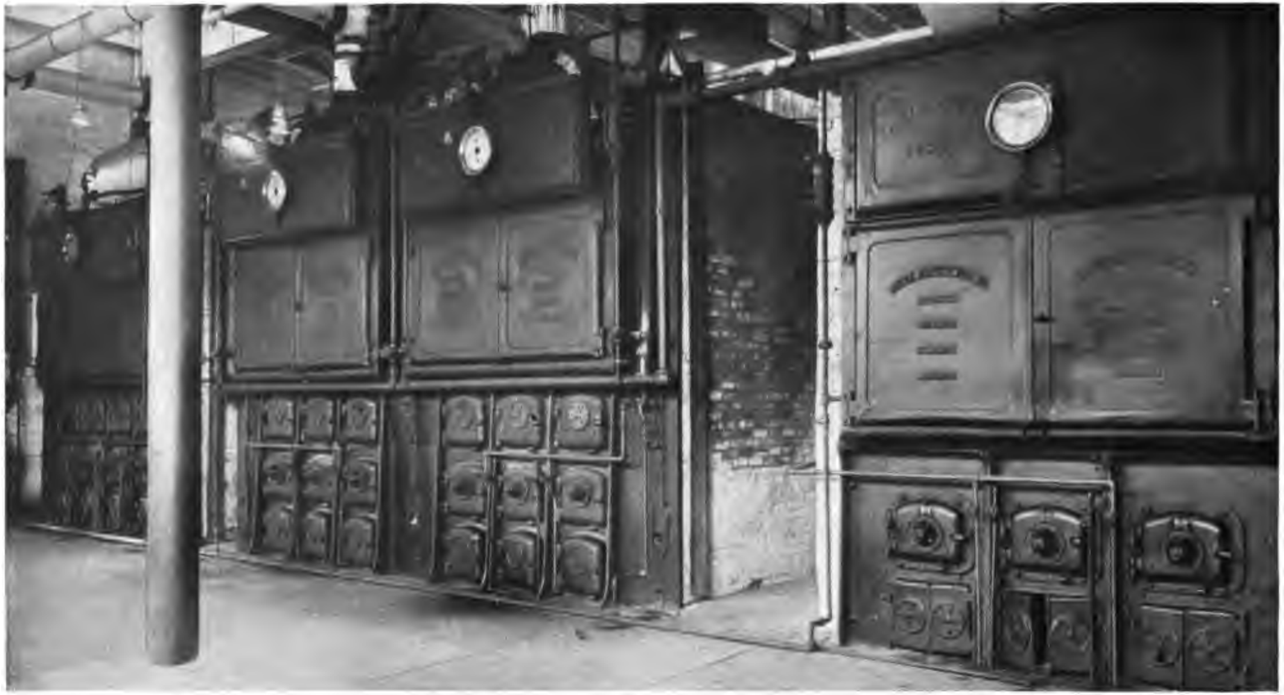
10. No ashes to get rid of in port or at sea.
11. Increased life of boilers and boiler room floor.
12. Decreased maintenance cost.

For Railroad Purposes:

1. General cleanliness in passenger service.
2. Elimination of fires caused by sparks.
3. Increased mileage at one loading.
4. Time saved in preparing a locomotive for the road.
5. Decreased labor charges.

For Metallurgical Purposes:

1. High temperature obtainable.
2. Absence of soot in dust chambers.
3. Decreased space required.
4. Increased capacity of furnaces, etc.
5. Decreased cost of handling fuel.
6. Ease and range of regulation.
7. Ability to reduce "sows" quickly.



Boiler-room of the American Brewing Co., Houston, Tex.

SPECIFICATIONS OF COMMERCIAL OIL FUELS

Gravity: Oil of a gravity between 15° Beaume and 30° Beaume is as a rule a suitable one for use under a boiler. It should not be too heavy to be easily vaporized by a jet of steam or to cause trouble in cold weather and not so light and volatile as to be flashy.

Moisture: Oil fuel should not contain more than a fractional percentage of moisture, sediment or impurities to be wholly satisfactory.

Flash and Fire Points: The oil should not flash at the temperature to which it will be subjected in storage or in transportation, or at ordinary temperatures in the boiler room.

Reduced Crude as Fuel: An ideal oil for commercial fuel is a crude petroleum which has been through a preliminary distillation, removing the light, flashy, volatile products as well as all moisture and sediment; and raising the flash point beyond any temperature met in handling the product.

GENERAL EQUIPMENT FOR OIL BURNING

1. A storage tank or tanks, the size of which will depend upon the capacity of the plant and upon the method of oil delivery.

2. A set of small pumps, in duplicate, to draw the oil from the storage tank and deliver it to the burners at the requisite pressure.

3. Oil burners, of which there are several excellent designs on the market.

4. The necessary piping between storage tanks, pumps and burners. The piping should be so arranged, by means of a relief valve at the oil pumps, as to enable any excess oil to return to the storage tanks. In localities where cold, freezing weather is experienced it is best to equip the storage tanks with a few steam pipes to be used in warming the oil when necessary.

5. The proper arrangement of furnace for the boiler under consideration.

ATOMIZATION OF THE OIL DELIVERED TO THE FURNACE

For the perfect combustion of any fuel, it is necessary that each particle be surrounded by an atmosphere of oxygen, as is the case in calorimetric determinations. In approaching this condition when using oil, it is necessary to spray the fluid as much as possible to enable the air supporting combustion to intermingle with the minute particles of oil. This is commonly accomplished in one of two ways.

Steam as an Atomizing Agent:

Under no circumstances can the admission of steam into the fire-box of a boiler be anything but detrimental to the temperature. If it is reduced to water vapor it gives up its latent heat only to absorb that heat again upon subsequent evaporation, and will absorb further heat when passing from the furnace as superheated steam. The original heat in the steam was taken from the boiler and should be considered lost as far as any possibility of regaining it is concerned.

It is necessary, however, to provide some means of properly atomizing the oil; no agent lends itself so readily to this purpose as steam from the boiler and consequently it is generally used. It should be taken from the dome, or from a point where the dryest steam can be secured, and piped direct to the burners; with no low places in the piping which would permit of the gathering of moisture, the piping being well protected by a suitable covering to reduce condensation to a minimum.

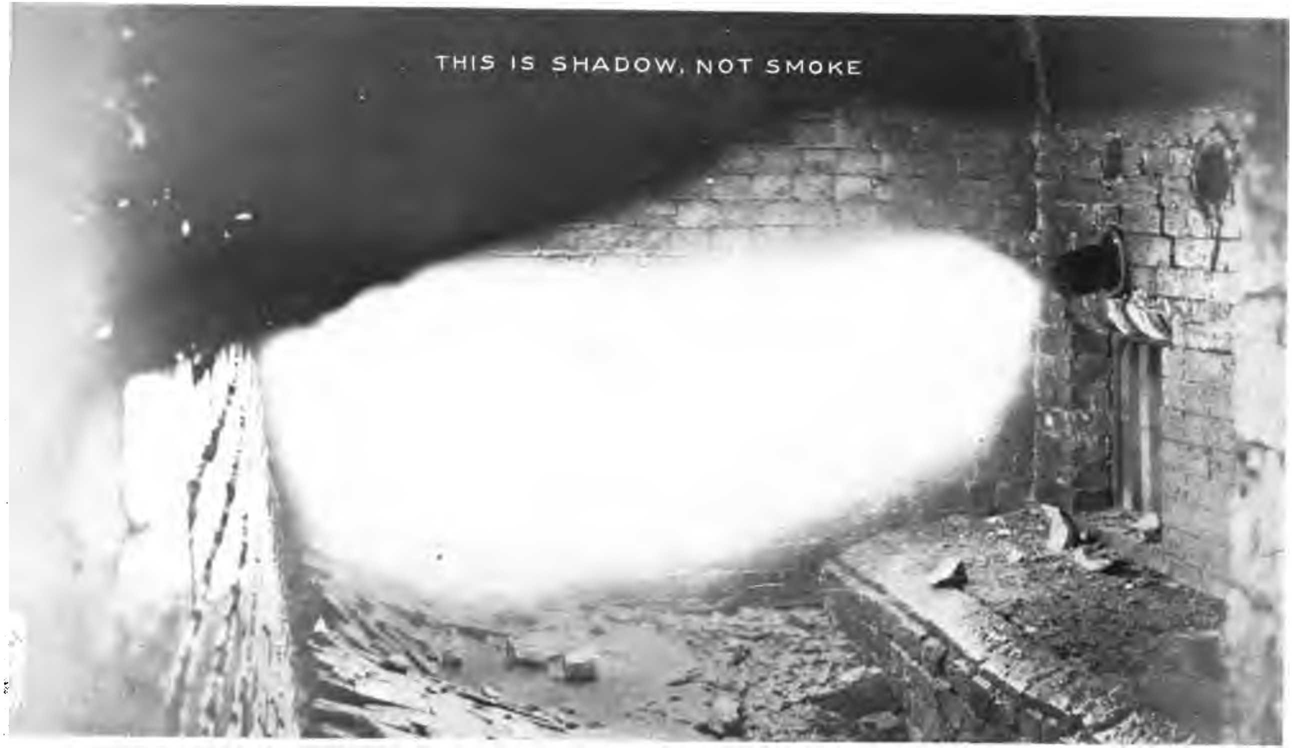


Photo of flame from Oil Fuel Burner in Boiler Furnace

It is usual to reduce the steam pressure to the burners by means of a regulating valve. When boiler pressures of less than 125 pounds are carried it is customary to eliminate the regulating valve.

Air as an Atomizing Agent:

When compressed air is available, or in large plants where the installation of an air-blowing unit would be warranted, this method of atomizing gives excellent results. The combustion is more complete than with steam and higher temperatures can be obtained, with a smaller percentage of steam used for the blowing unit than is ordinarily used through the burners.

Air pressures as low as *twelve* ounces may be used satisfactorily, but oftentimes a pressure of four or five pounds is desirable. The air has the effect not only of atomizing the oil, but at the same time aids combustion.

The oil flame, when using low pressure air to atomize, is shorter than when steam is used and is of an intense white color indicating that combustion is more rapid and complete. Unless the oil is heated to a temperature approaching its flash point before admission to the burners, the atomization is apt to be incomplete; particles of carbon will be seen dropping to the furnace floor forming a carbon deposit there and producing a smoky flame.

In plants, such as cement plants, brick plants, which cover a wide area and which require heat at points distant from the central steam supply, etc., the use of high or low pressure air for vaporizing the oil is especially desirable. In this case the installation should cost no more than where steam is used, and it eliminates condensation losses, frozen steam lines, etc.

Pressure of Oil at the Burners.

It has been observed in many plants where oil is being used under the boilers that pressures of 75 lbs. to 125 lbs. of oil are maintained by the oil pumps and the regulation of oil is effected by a valve near the burners. It is very obvious that such pressures are not necessary, if the piping is of proper size to carry the amount of oil required, as it is usually only necessary in such cases to "crack" the valve between the pump and the burner in order to secure sufficient oil. This means considerable reduction in pressure between the valve and the burner, consequently the effect of the pump pressure for atomization is not obtained.

With "internally mixed" burners, where the oil and steam come together inside the burner, it is necessary to maintain sufficient pressure of oil to overcome the back pressure of the steam, and at the same time supply the required amount of oil. This is usually about 30 lbs. to 50 lbs. With "externally mixed" burners, however, it is only necessary to have an oil pressure sufficient to insure the free passage of oil through the piping, which will be (with the proper size pipe) about 4 lbs. or 5 lbs.

Pre-Heating the Oil.

It is desirable to heat the oil to a temperature of approximately 150° F. A variation from this temperature may be required to meet local conditions and on account of the character of the oil used. 20% from the temperature stated will probably meet the majority of cases.

At no time should the oil be heated above the flash point.

In cities where the insurance rules require the use of pressure pumps rather than a gravity system, this heating can easily be done by passing the exhaust steam from the pumps through coils in a heater, connected in series between the pressure pumps and the burners. The preheating of the oil is sometimes accomplished by passing it through coils in the uptake of the boiler or in the furnace proper. This is not to be recommended as the action of the hot flue gases or the high temperature in the furnace is very detrimental to the coils and they are sure to fail in the course of time, with the possibility of fatal results.

In case exhaust steam is not available, the oil should be heated by live steam. The specific heat of oil fuel is only about one-half that of water, hence very little steam will be required.

A slightly better economy is obtained by preheating, as it increases the fluidity of the oil and consequently does not require as much steam or air to effect the atomization.

The "flash" point of oil is that temperature at which it gives off sufficient gas to flash but not burn continuously. The latter being the "fire" point.

When oil fuel is heated beyond the flash point, decomposition begins to occur, causing carbon to be precipitated; this will clog the oil lines and burners, causing no little inconvenience as well as producing an unnecessary hazard in case of a broken oil line. If, however, the heater does not raise the temperature of the oil above the flash point, there will be no trouble or danger from this source.

FURNACE ARRANGEMENT

The proper arrangement of a boiler furnace for the burning of oil does not differ materially from one arranged for the use of coal, and the change from one to the other is simple and inexpensive.

The fitting will naturally depend on the type of boiler and the burner to be used. Vertical water tube boilers will require a slightly different construction from that suitable for horizontal boilers of water tube or tubular type.

In general, the construction will consist in covering the grate bars with a good grade of fire-brick, leaving a suitable air space directly under and in front of the tip of the burner. The area of air space will depend upon the available draft as well as the size of boiler, etc. The burner is usually placed through an opening in the fire door space, which space has been closed by fire-brick. Beyond the air opening the fire-brick on the grate bars should be laid loosely for a distance of two or three feet and about 18 inches wide, to permit air to filter up through.

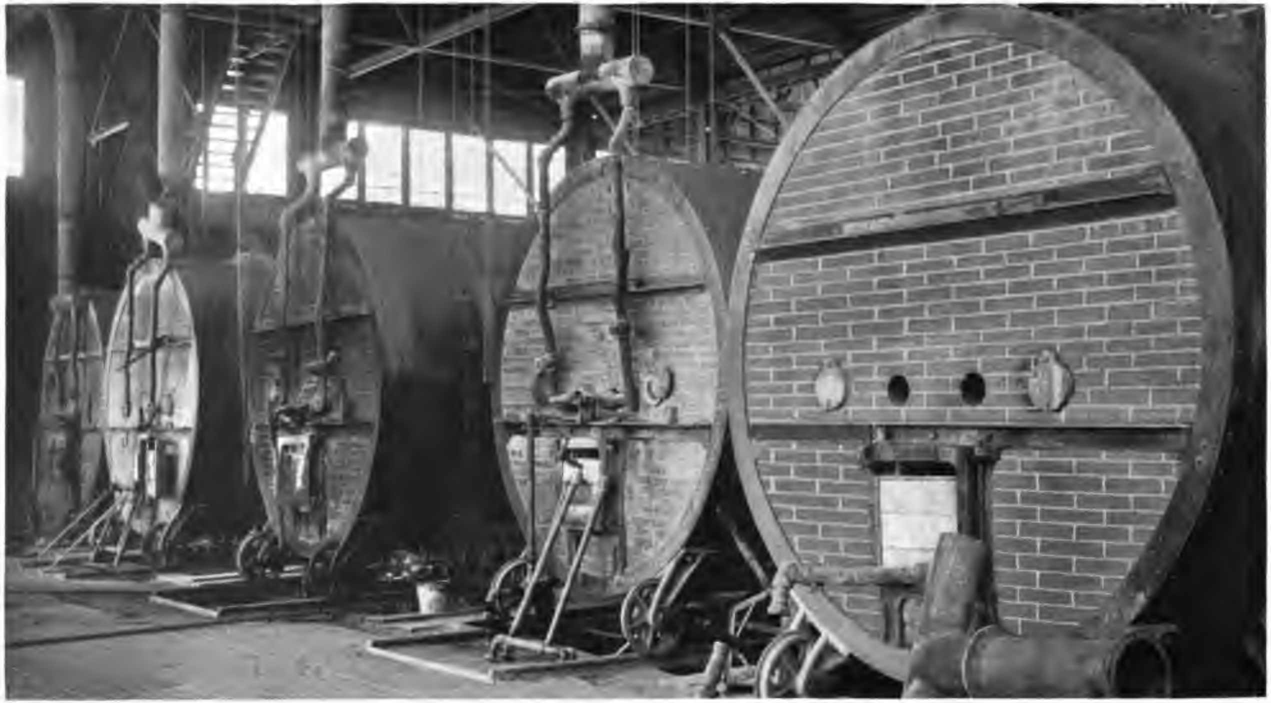
The regulation of air should be done by the damper and also by the ash-pit doors. Some engineers prefer to divide the ash-pit horizontally into two sections by fire-brick, bringing the air in through the lower and returning through the upper passage to the air opening at the front of the furnace, thus raising the temperature of the air slightly. It is not generally believed that this construction increases the efficiency to any extent.

The target—which should always be used in order to have a heated mass in front of the burner; thereby generating a gas and re-igniting immediately after a momentary stop in the flow—should consist of a fire brick checker-work about 38″ to 40″ from the tip of the burner and about 15″ to 18″ high, so arranged as to prevent any oil particles from passing through it without striking the white hot brick. Care should be taken to so construct the furnace and target as to prevent the flame striking the water heating surface of the boiler in such a way as to localize the heat. It is often advantageous to protect the bottom row of tubes in water tube boilers by specially constructed fire-brick. This is frequently done in coal burning furnaces.

The successful burning of oil fuel requires a larger furnace volume than coal, the essential requirement being the perfect intermingling of the finely divided oil particles with the air supporting combustion in an incandescent furnace. Hence, it is sometimes desirable to remove the grate bars entirely when changing from coal to oil.

Owing to the many designs of oil burners, piping and furnace arrangements on the market, it is impossible in a publication of this kind to show cuts or sketches which would cover the peculiar requirements of all power plants. Moreover, it would be confusing to the prospective fuel oil user, who is perhaps not familiar with the subject, to determine just which installation would be productive of the most economical results for his particular plant.

The Texas Company has had a wide experience in all matters pertaining to the use of oil as fuel, and information or advice will be cheerfully given upon application.



Kiln-room of the Southwestern States Portland Cement Co., West Dallas, Tex.

OIL BURNERS

It is not the purpose of this publication to point out the good points or defects of any particular oil burner. It will be sufficient to say that there are a number of very good makes on the market, some of which are perhaps more suitable for a particular service than others, and it is largely a question of selecting the burner which will be the most economical in the service for which it is to be used.

In general it may be said that the distinguishing feature of oil burners is not so much the effectiveness of the atomization as the amount of steam required to properly atomize the oil. The variation in this respect among the different burners being from 1% to 10% and more of the total evaporation of the boiler, although it should be stated that this depends largely upon the operation.

Oil burners are of two general classes:

Internally Mixed Burners.

In this type of burner, the oil and atomizing agent (steam or air, as the case may be) come together inside the burner and issue from the burner tip in a more or less finely divided spray.

Externally Mixed Burners.

The mixture in this type takes place outside of the burner, the steam or air and oil discharge passages usually terminating at the burner tip in the same vertical plane, the oil being in the center and surrounded by the atomizing agent.

When using oil of a fairly light body, the externally mixed burners possess the advantage of not requiring much oil pressure, as there is no back pressure of steam or air to be overcome. Elevating the oil storage tank about 15 feet above the burners will in most cases furnish a sufficient pressure of oil.

Some internally mixed burners are so designed as to secure a jet effect from the steam which draws the oil from the supply pipe, thus doing away with oil pressure pumps.

Mechanical Burners.

Oil burners depending upon either a comparatively high oil pressure or upon the rapid revolving of a circular disc to effect the atomization of the oil are termed mechanical burners. Such burners have not come into general use at the present writing, but the field looks very promising for future developments along this line.

In either of the types of mechanical burners mentioned, the use of steam is indirectly necessary, since the high oil pressure maintained by the pump or the rotation of the circular disc will require the use of steam. The points to be considered are the effectiveness of the atomization, the simplicity and durability of the mechanism and the amount of steam used as compared with other types.

The U. S. Navy is using a system of this kind on some of its ships, maintaining oil pressures varying from 50 lbs. to 200 lbs., depending on the speed of the boat and operating as many as eleven burners under one boiler.

Burners depending upon pressure and the shape of the orifice to effect the atomization should have the oil well preheated and forced to the burners at a constant pressure. It is also considered essential to supply the air supporting combustion under a pressure sufficient to give it a velocity approximately equal to that of the oil as it leaves the burner, and in such a manner as to insure a speedy and intimate intermingling of the two. The best results are obtained when the air is preheated.

Number of Burners to be Used.

The tendency in most oil burning plants seems to be to use too few burners rather than too many.

While the majority of oil fuel burners are rated at 75 to 100 Boiler Horse Power, it is always desirable to use a sufficient number to insure a solid sheet of fire extending across the furnace to prevent air supporting combustion from passing up the stack without performing its function as explained on page 89 and also to prevent localizing the heat in the furnace.

Experiments have proven that a burner is less efficient, as regards the amount of steam used for atomizing, when being forced than it is when used at its normal rating.

GENERAL DIRECTIONS FOR OIL FIRING

Lighting the Fire.

Make sure that no oil, due to leaky valves or fittings, has accumulated in the furnace or ash-pit while the boiler has been standing idle. If such conditions occur, open the flue dampers and ash-pit doors and admit steam through the burners until any gases which may be present have been driven up the stack.

If oil pumps are used, start one of them (taking care that all connections are properly made), and allow the oil to flow back to the oil tank through the overflow line. Maintain the required oil pressure as indicated by the gauge on the discharge line between pump and burners.

Open the damper and ash-pit doors.

Open the steam valve on the line supplying the burners with steam, just enough to force out what water of condensation may have collected. After the steam line has "warmed up," light a torch made of asbestos wicking on the end of a twisted wire handle (the wicking being saturated with oil) and hold this torch at the tip of burner or directly in front of it. Gradually "crack" the valve on the oil line until the oil ignites. Avoid standing directly in front of furnace doors.

In warming up a cold boiler, watch your fire closely, as it may go out, due to irregularity of oil flow, etc., the furnace not being sufficiently heated to ignite the oil when the flow is re-established. Before relighting the burners in such cases make sure that gases are expelled as per instructions in the first paragraph on this page. Smoking will occur until the furnace and its gas passages have become hot.

Water-works Plant, Houston, Texas

Proper Combustion.

It is difficult to instruct a fireman on paper as to proper condition of his fire for perfect combustion, but a very little experience will enable him to tell at a glance if any one burner is producing a smoky flame, and he will soon learn to regulate the steam and draft to obtain the most satisfactory results.

A Common Fault.

If a fireman has no pride in reducing his employer's fuel bill to a minimum, he will be apt to effect the regulation of his fires by the oil valve alone, leaving the steam valve open sufficiently to take care of the maximum oil supply. It should be borne in mind that there is a definite relation between the amount of oil being used and the necessary amount of steam to properly vaporize that oil. The use of more than that amount of steam is a willful waste of fuel.

Putting Out the Fire.

Close the oil valve or shut down your oil pump.

Close the steam valve to burners.

Drain the steam end of oil pump.

Close ash-pit doors and damper after boiler has cooled sufficiently to prevent blowing off.

NOTE: When burners are lighted do not have the torch lying or standing around but immediately put the asbestos wicking into a receptacle made of a 2″ nipple about 10″ or 12″ long, having a cap on one end.

In the case of burners located at the bridge wall and firing toward the boiler front, a piece of oily waste may be lighted and thrown into the furnace for the purpose of igniting the oil. Before doing this however open flue dampers and ash-pit doors and steam fire-box thoroughly to discharge lingering gases, then throw in the lighted waste before turning on the oil.

COLUMBIA PLANTATION

Located on the west side of the Mississippi River, Parish of St. John the Baptist. Property of Caire, Graugnard & Co.

Amount cane ground last year . . .	60,000 tons
Amount of sugar made	7,500,000 pounds
Quantity of Oil Fuel used per ton of cane	8 gallons

This refinery uses Oil Fuel supplied by The Texas Oil Company.

OIL FUEL IN SUGAR MILLS

The sugar mill engineer's first and last thought is reliability. Every minute lost during the grinding season has a dollar sign prefixed to it. He spends eight to nine months each year getting ready for the three or four months' day and night period of rush. To be perfectly sure of his fuel supply, to know that, when needed, he can develop with his equipment his full rated boiler horse power and more; to see his fuel supply in storage before the season begins and to know that it will remain unchanged in quality, ready to use at a moment's notice; all this means more to him than any comparative evaporative figures, even more in some cases than comparative prices.

Every sugar mill engineer knows that to successfully burn his bagasse, it is necessary that it be cut up fine and well dried by a hot air blast; and even then, if fed too fast, the result is apt to be a partial failure, as it should be burned at a high rate of combustion. The installation of a single oil burner in the bagasse furnace will enable this inferior fuel to be completely and rapidly burned, no special design of furnace being necessary to enable oil to be used with bagasse.

Sugar mills are often located in out of the way places, and it is difficult to deliver solid fuel, either due to excessive freight rates or on account of the general condition of the country. Oil fuel lends itself readily to these conditions as the delivery may be at points four or five miles from the mill, where an oil barge will fill up the storage tanks, which are connected to the mill by pipe line.

When coal is used in sugar refineries, it is necessary to use the very best grade, since inferior grades of coal slack badly when stored; and, moreover, the freight is just as much for inferior coal as for the better grades. Hence the price per ton is usually high.

Another point which appeals to the sugar mill operator is the labor charge. He knows that good firemen are hard to obtain, especially when he can use them but three months in the year and cannot afford to retain them during the idle period. He is consequently forced to obtain new help for each season's grinding.

When using oil fuel, one man does the work of a dozen firemen, ash-handlers, unloaders, etc., and, moreover, he can usually arrange to keep this man the year around.

The ratio of oil used to tons of cane ground and manufactured into sugar depends upon the quality of the cane and the ability to run full load. In the Louisiana sugar district, where the cane has about 10% fibre, they obtain about three pounds of juice to one pound of bagasse (with 75% extraction). As one pound of bagasse contains about 4,200 B.T.U., and as a boiler and grate efficiency of 55% is all that is obtainable, there will be available in the form of steam only about 2,300 B.T.U., which is not enough to work up the three pounds of juice.

A fair average for Louisiana sugar mills is about six to eight gallons of oil fuel per ton of cane ground and manufactured into sugar, when the entire amount of bagasse available is also burned.

In a well equipped and up-to-date Louisiana sugar house, the green bagasse, direct from crushing plant to the furnaces, furnishes in the neighborhood of two-thirds of the necessary fuel.

The internally fired boiler seems to give the best satisfaction and when set with a Dutch oven in front will develop on the average about 24 boiler horse power hours from the bagasse of one ton of cane at 75% mill extraction. The theoretical results which are given below are considerably higher.

One ton of Louisiana cane at 75% mill extraction yields 1500 pounds of juice and 500 pounds of bagasse. The latter contains about 4200 B.T.U. per pound, of which 55% is transmitted to the boiler water.

$$\frac{(4200 \times 55\%) \times 500}{970.4 \times 34.5} = \text{about 34 boiler horse power hours.}$$

or nearly 1½ boiler horse power per day of 24 hours.

While the above results have been obtained under exceptionally favorable conditions, they should not be given undue consideration, and are of value only in showing what has been accomplished. Like all other power installations, sugar mills are subject to many varying conditions, such as quality of the cane, weather, interrupted service, sudden demands for power, etc., all of which affect the economical operation of the plant as a whole.

It is the consensus of opinion of the majority of consulting engineers, superintendents and managers of Louisiana sugar mills, that the bagasse from one ton of average cane at 75% mill extraction (which will be obtained with a six-roller mill) will develop about one boiler horse power per day of 24 hours. The

RESERVE PLANTATION

Located on the east side of the Mississippi River, Parish of St. John the Baptist. Property of Leon Godchaux Co., Limited.

Amount of cane ground last year .	140,000 tons
Amount of sugar made	21,500,000 pounds
Quantity of Oil Fuel used per ton of cane	7 gallons

This refinery uses Oil Fuel supplied by The Texas Oil Company.

bagasse from tropical cane will do somewhat better than this, as weather conditions permit of a longer drying period, which increases the percentage of fibre.

A modern Louisiana sugar house requires about 1½ boiler horse power for each ton of cane handled in 24 hours. Hence, a 1000 ton house requires 1500 B.H.P. of which 1000 H.P. is obtained from bagasse and 500 H.P., from the auxiliary fuel, which is almost invariably oil.

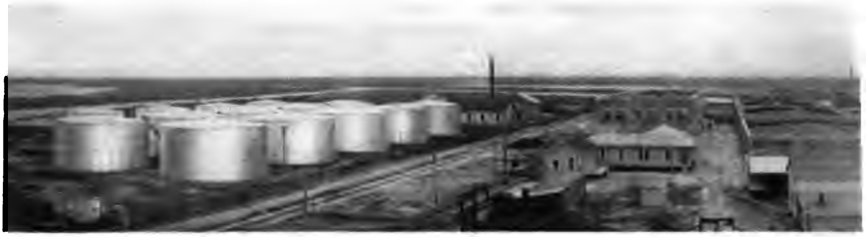
Sugar mill boilers are usually divided into those burning bagasse alone, and those using oil alone; however, it is customary to install one or more oil burners in each bagasse furnace for the purpose of increasing the horse power if necessary; and for facilitating the firing up of a cold boiler with bagasse by simply lighting the oil burner until the bagasse is burning freely, thus saving about three hours' time as well as considerable wood or coal which would be used for this purpose.

When using oil in connection with bagasse, the burner is placed through a hole in the boiler front and directed downward, in such a way as to direct the oil flame into the flame from the bagasse and not on the bagasse directly, as this would cause a deposit of carbon due to the oil striking this comparatively cold fuel.

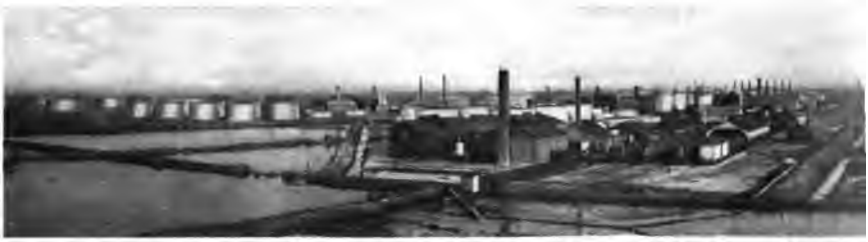
When using stacks of less than 100 ft. height it is advisable to use a forced draft (usually about 4 oz.) for the proper combustion of bagasse. Since stacks for oil burning furnaces need not be over 70 ft. high, it is sometimes advisable to install a forced draft system for the bagasse burners, thus saving the cost of the additional height of stack.

A very comprehensive and interesting article entitled "Fuel in the Sugar House," by Prof. Chas. E. Coates, appeared in the Louisiana Planter, April 14, 1906. This article deals with the use of oil, coal, bagasse and wood.

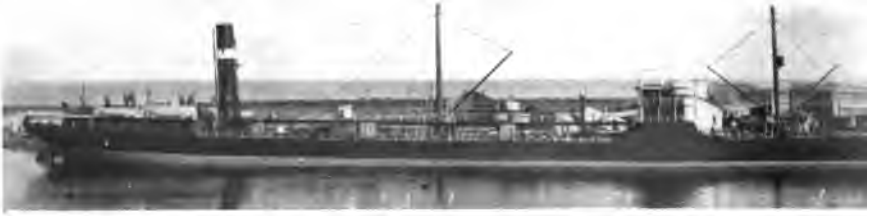
The Texas Company has, in the past ten years, furnished millions of barrels of oil fuel to the Sugar Plantations of Louisiana, and is proud of its record of reliability, both as to quality of oil and prompt service.



The Texas Company's Docks a



The Texas Company's



The Texas Company's Docks a

ıd Terminal at Port Arthur, Tex.

Vorks at Port Arthur, Tex.

ıd Terminal at Port Arthur, Tex.

OIL FUEL FOR METALLURGICAL OPERATIONS

Fuel for metallurgical purposes must have certain properties not so essential in boiler furnaces. This is especially true in connection with reverberatory practice. A coking coal will not give satisfactory results owing to the rapidity with which the volatile matter is given off, leaving a heavy bed of coke on the grates which burns very slowly.

The use of pulverized coal has its disadvantages, also, one of which is the difficulty of regulating the air supply. If too much is admitted, the result will be a decrease in furnace temperature, and if too little air is supplied, incomplete combustion will result, often causing a deposit of carbon on top of the charge, thus forming a non-conductor which seriously impairs the efficiency of the furnace.

Another objection to the use of pulverized coal in reverberatory furnaces is the filling of flues with fine ashes, rendering the recovery of waste heat from the furnace gases an impossibility.

Numerous extended experiments with oil fuel in connection with smelting operations have been conducted by men well versed in this science, and the results obtained have been extremely satisfactory. Perfect regulation of air and oil are obtainable at all times with a minimum labor and handling charge, and the completeness of combustion insures the recovery of a high percentage of the heat in the escaping gases. A paper read before the Institute of Mining and Metallurgy, London, Nov. 18, 1909, by Dr. L. D. Ricketts, general manager of the Cananea Consolidated Copper

Company, Cananea, Mexico, covers the subject of oil versus coal in smelting operations very thoroughly. Some data taken from this article is given below:

COAL

"During this period (9 months) the highest monthly cost per ton of dry charge treated was $8.49, and the lowest cost was $4.75. The highest cost per ton for coal alone was $6.16, and the lowest was $3.32. The highest percentage of coal used was 61 and the lowest was 33.6 per cent. It should be noted that the least coal consumption occurred during the two months in which we used the pulverized coal, and during which there was no steam generated from the waste gases. The average net cost, giving fuel credit to the reverberatory for the period in question, was $5.49 per ton made up of the following costs: Labor, $0.795; supplies, $0.293; coal, $4.067; power, $0.177; miscellaneous, $0.13; repairs, $0.358; flux, $0.01; total, $5.83; from which is deducted a steam credit of $0.34; leaving a net cost of $5.49 per ton smelted.

"The works closed down in the latter part of October, 1907, and experiments were stopped for the time being, but it was thought we had proceeded far enough to demonstrate that the coal obtainable from the Southwest was not well adapted to reverberatory practice."

OIL

"Costs for Five Months in 1908.

Labor, operating and repairs.....	$14,829.39
Shop expense.................	1,966.64
Supplies (firebrick, etc.)........	5,613.13

Oil Fuel	56,217.15
Power	445.83
Miscellaneous expense	533.78
Total	$79,605.92
Cost of barren fluxes	609.90
Total	$80,215.82
Less steam credit	24,267.37
Net account smelting	$55,948.45
Average cost per dry ton smelted,	$1.785

"The actual water evaporated per pound of oil burned in the reverberatory was 6.74 lbs., whereas the pound of oil burned under the smeltery power-house boiler evaporated 13.96 lbs. Taking account of the temperature of feed water and converting into evaporation from and at 212 degrees F., we have the following figures: Evaporation per pound of oil burned in reverberatory, 7.45 lbs. Evaporation per pound of oil burned under power-house boilers 16.08 lbs.

"Costs Per Ton Smelted, First Six Months of 1909:

Labor, operation	$0.24
Labor, repairs	0.16
Supplies	0.22
Oil Fuel	1.73
Power	0.02
Miscellaneous	0.08
Total direct costs	$2.45
Cost of fluxes	0.08
	$2.53
Steam credit	0.77
Net cost	$1.76"

BEST TONNAGE AND COST RECORDS

"The record month as regards both tonnage and costs was January, 1909. In this month we smelted:

Flue dust	4639	tons
Calcines	2711	"
Silicious ores	359	"
Fluxes	440	"
Total	8149	"

"An average of 263 tons per day.

"We used 7003 bbl. of oil, of which 3102 bbl. were recovered as an equivalent in steam, and 3901 were charged to smelting.

"The charge contained 7.13 per cent. copper and 7.51 per cent. sulphur; the matte contained 40 per cent. copper, and the recovery of copper in the matte for the month was 95.97 per cent. The slag had the following partial composition:

	Per Cent.
CuO	0.41
SiO_2	41.20
Al_2O_3	11.00
FeO	34.60
CaO	7.30

"The net cost per dry ton smelted, including cost of fluxes, was $1.29 per ton, after $0.67 per ton had been deducted from the gross cost on account of steam credit."

The results as given by Dr. Ricketts show the value of fuel oil for metallurgical operations, and while the cost per dry ton smelted is very low as compared to that when using coal, it is estimated that it can be reduced to $1.40 per ton, or even lower, by the use of economizers in the boiler stacks, thus further utilizing the heat of the waste gases by increasing the temperature of the boiler feed water.

This company found that a notable reduction in labor was effected by changing from coal to oil fuel; that about three barrels of oil were equivalent to a ton of coal, and that the evaporation of water into steam in the waste heat boilers was 50% of what it would have been had the oil been burned in the boiler furnace.

The use of oil in reverberatory practice requires a burner giving a long flame, and not too rapid combustion in the front part of the furnace. These are readily obtainable. During the year 1908, The Texas Company contracted with the Cananea Consolidated Copper Company for oil fuel in amounts not exceeding 35,000 barrels per month, and is prepared to act in an advisory capacity with prospective users of oil fuel in connection with reverberatory furnaces, roasters, dryers, boilers, etc.

OIL FUEL USED IN CONJUNCTION WITH COAL TO MEET PEAK LOADS AND FOR BANKED FIRE PERIODS.

In an article in the June 20, 1911 number of "POWER," Mr. Herbert A. Wagner describes an arrangement of furnace design whereby oil is used for the above purpose.

The boilers are the B. & W. type rated at 650 H. P. each. The oil is fired from the rear, four (4) burners being fitted to each boiler. By shortening the bridge wall and putting in a horizontal baffle on the bottom row of tubes from the bridge wall to the rear end of the tubes, the gases of combustion for both oil and coal traverse the same path, the second vertical baffle being also shortened. Air to support the combustion of the oil is taken in from the rear.

The following results having been obtained with this arrangement:

> One per cent. of the total evaporation is used to atomize the oil.
>
> It was found to be cheaper to bank with oil than with coal.
>
> One burner is used for a pilot and for banking.
>
> Furnace changes were slight.
>
> With coal alone 1188 B. H. P. was developed.
>
> With oil alone 702 B. H. P. was developed.
>
> With oil and coal together 1445 B. H. P. was developed.
>
> With oil and coal together a maximum for one hour with one boiler was 1632 B. H. P.

"It has been found that 2000 K. W. of station load can be carried by each boiler when using coal and oil together with as much ease and certainty as 1200 K. W. per boiler can be carried by coal alone. This shows under operating conditions a gain in capacity of 66⅔ per cent. by the use of oil or a saving of 40 per cent. in the cost of the boiler plant for a given capacity."

"Tests have shown that a cold furnace with water in the boiler at 142 degrees F. could be made to steam at 175 lb. pressure in 25 minutes with oil fuel as compared with 42 minutes with coal."

"May 12, 1911: The steam station was carrying 2000 K. W. with four coal-fired boilers in service and four additional boilers banked by means of one oil burner under each. The transmission service was suddenly interrupted and a load of 7600 K.W. thrown on the steam plant. Oil was turned onto the four boilers in service and the four banked boilers; the steam pressure was maintained and in four minutes the boilers were blowing off."

Oil Fuel for Forge Work, Annealing Furnaces, etc.

The adoption of oil fuel for forge and furnace work by the U. S. Government and many large railway and manufacturing shops, is the result of extended experiments to determine the most suitable fuel for this class of work.

The wide range of regulation, the ease and rapidity with which a welding heat can be obtained on large and small work, combined with simplicity of apparatus and minimum labor charge, all show the superiority of the liquid fuel.

By the use of two valves the operator has his fire under perfect control at all times and can change instantly from a slow annealing to a dazzling white heat. When the work is ready for the hammer, the

U. S. S. Delaware. Burning The Texas Company's Oil Fuel oil may be entirely shut off until ready for use again affecting a considerable saving in fuel in this way.

In the repair and straightening of structural iron work, the fire may be carried to the work by means of small fifteen or twenty-gallon oil holders, doing away with the expensive handling of heavy work.

In annealing furnaces an even heat of any desired intensity can be maintained over large areas. The boiler maker finds this feature especially desirable in flange and other similar work.

For welding large or small work, drop forge processes, forging crank shafts and other large work the oil fuel is invaluable. Long irregular-shaped pieces are readily brought to any required heat in the oil furnace.

The following data was obtained at representative plants using oil in steel, brass, and annealing furnaces.

20 gallons of oil required to "bring down" 100 pounds of steel, 3 hours required to "bring down" six pots of steel containing 100 lbs. each.

2 gallons of oil required to melt 100 lbs. of brass using a 12 ounce air pressure, 40 minutes to "bring down" a charge of 500 lbs. of brass.

Annealing Furnaces.

8 Brown & Sharpe, No. 2 case hardening furnaces, arranged in pairs.

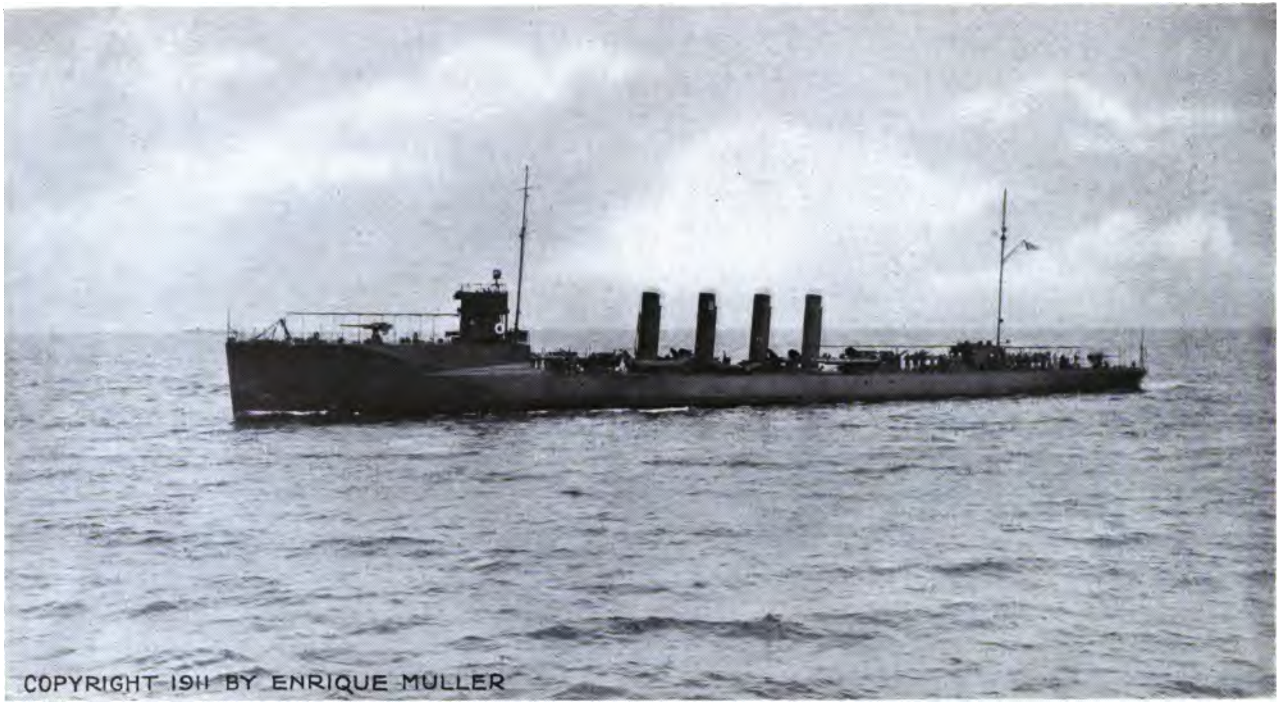
1 burner to each furnace.

Atomizing air at 1½ lb. pressure from a positive pressure blower driven at 175 R. P. M. and delivering 3.75 Cu. Ft. per revolution.

Oil Pressure on burners, 7 lbs.

$2\frac{1}{16}$ gallons oil per hour for 8 furnaces.

1500 to 1800 degrees F. is the uniformly distributed heat of the furnaces.



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U. S. S. Burrows. Burning The Texas Company's Oil Fuel

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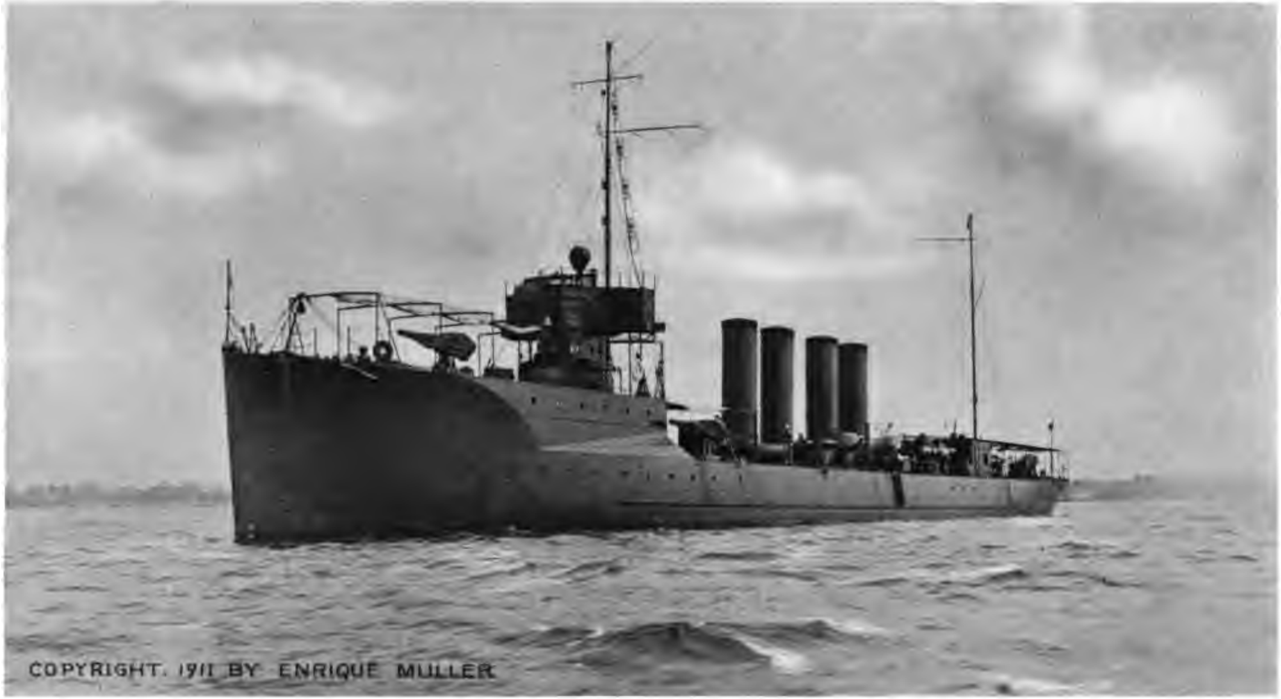
U. S. S. Drayton. Burning The Texas Company's Oil Fuel



U. S. S. Paulding. Burning The Texas Company's Oil Fuel

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U. S. S. Drayton. Burning The Texas Company's Oil Fuel

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U. S. S. Paulding. Burning The Texas Company's Oil Fuel

There would be no loss of strength in the fleet due to absence of any vessels coaling.

Scouts, destroyers and other torpedo craft could put into port for refilling.

As bunkering with oil takes little labor, the crew could secure a valuable rest.

Such an interval of rest would be doubly important in the tropics.

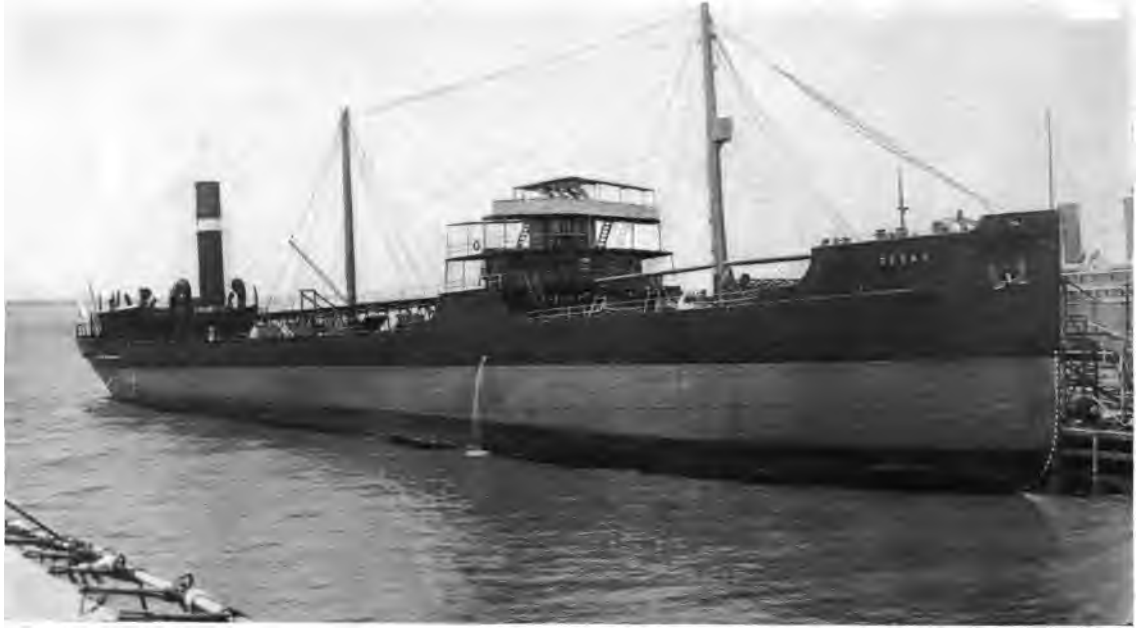
The fire rooms would not be the usual "Inferno." There would be no shovelling of coal under exhausting conditions and terrific temperatures. It would be necessary only to watch valves and indicators.

Greater efficiency of crew, possibility of intervals of rest and easier conditions of labor, would increase the value of the units in actual warfare.

During bunkering with oil, minor repairs and adjustments to machinery could be made.

In case of grounding involving the necessity for lightening the vessel, coal is difficult of removal and there is great danger of bad weather coming on before the vessel can be floated.

Oil fuel can be pumped out with little labor in a very short time.



The Texas Company's Tank Steamship "Texas"
Flagship of The Texas Company's Fleet

OIL FUEL DATA

397 ft. length, 52 ft. beam moulded, 30 ft.
to Avonmouth, England,
Engine 27″, 44″

	Mean Draft	Distance Ship	Distance Wheel	Slip of Wheel	Speed of Ship	Steam
Dept. Sabine. 3.03 p.m., Dec. 13, '08 Arrived Avonmouth 5.34 p.m., Jan. 1, '09 Elapsed time 18 d., 20 hrs., 31 min.	24 ft. 5½ in.	4658 Kts.	5115 Kts.	8.9%	10.3 Kts.	185 lbs.
Dept. Avonmouth. 11.28 p.m., Jan. 5, '09 Arrived Sabine 9.23 a.m., Jan. 24, '09 Elapsed time 18 d., 16 hrs., 6 min.	17 ft. 1 in.	4932 Kts.	5272 Kts.	6%	11 Kts.	185 lbs.

OIL FUEL DATA OF S. S. "TEXAS" on Voyage 2

Dept. New York. 3.41 p.m., Nov. 6, '10 Arrived Port Arthur 4.09 a.m., Nov. 13, '10 Elapsed time 6 d., 13 hrs., 33 min.	14 ft. 6 in.	1815 Kts.	1941 Kts.	6%	11.5 Kts.	185 lbs.
Dept. Port Arthur 2.45 p.m., Nov. 17, '10 Arrived New York 2.50 p.m., Nov. 24, '10 Elapsed time 6 d., 23 hrs., 14 min.	21 ft. 7 in.	1861 Kts.	2028 Kts.	8%	11.13 Kts.	185 lbs.

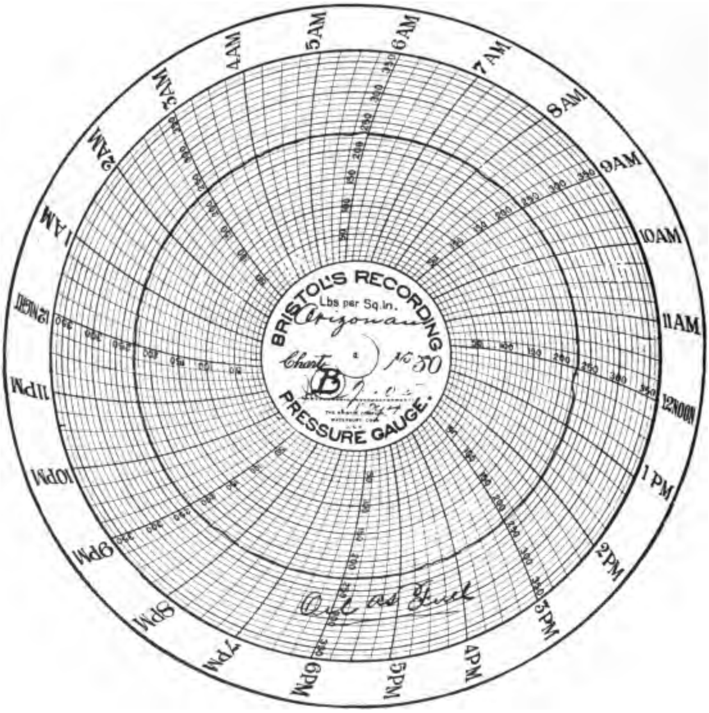
OF S. S. "TEXAS"

depth moulded. Voyage (4) Sabine, Texas,
nd return to Sabine, Texas
74″ x 51″ stroke

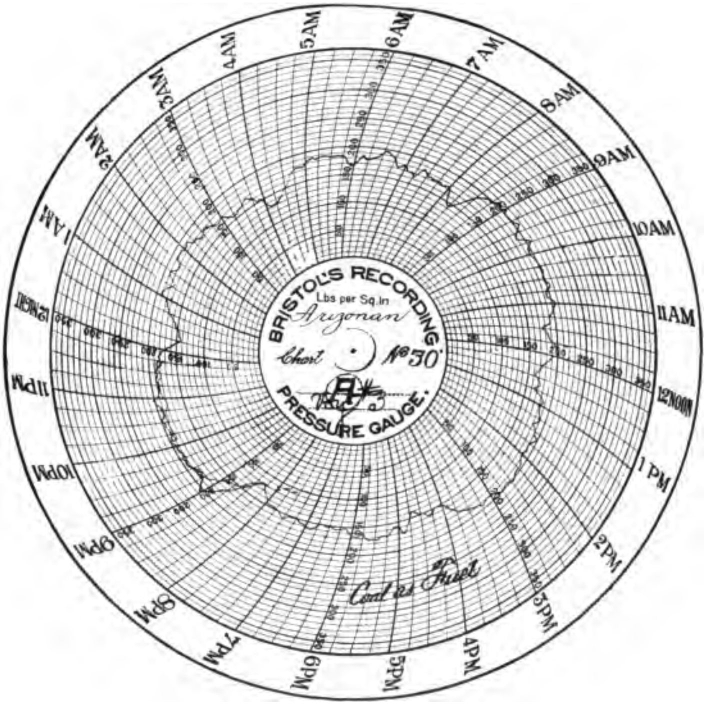
Vac.	Average Rev's per min.	Oil Pressure	Atom Pressure	Furnace Draft	Temp. Feed water	Average I. H. P.	Oil Fuel Consumed	Av. Weight of Oil per I. H. P.
25 in.	63.6	28 lbs.	1⅜ lbs.	0	220°	2005	120700 gals.	1.011 lbs. per H. P. hour
25 in.	66.3	28 lbs.	1⅜ lbs.	0	220°	2178	113635 gals.	.91 lbs. per H. P. hour

7, New York to Port Arthur and return to New York

25 in.	69.3	28 lbs.	1⅝ lbs.	0	210°	2358	47580 gals.	.971 lbs. per H. P. hour
25 in.	68.3	28 lbs.	1⅝ lbs.	0	210°	2389	50560 gals.	.961 lbs. per H. P. hour



Steam Pressure Chart from S. S. Arizonan—Oil as Fuel



Steam Pressure Chart from S. S. Arizonan—Coal as Fuel

COMPARATIVE DATA: COAL vs. OIL F

American-Hawaiian

Covering passages from New York, Pacific Coast po
via Straits of Mag

Gross tonnage: 8672, Twin Screw, Three Boilers, Howden

	Mean displacement out	Mean displacement home
Voyage No. 3 Using Coal...............	16,882 tons	16,660 tons
Voyage No. 4 Using Oil.................	15,930 tons	17,280 tons

Actual cost of fuel consumed on these voyages was pra
25 days saving in time on the round voyage, of whic
ing ports on voyage No. 3.

Saved in victualling and manning....................
Increased earnings: { Freight earnings increased by 150 tons Eastbound...
{ Disbursements at coaling ports..................
Total..............................
25 days saved at $500.00 per day, net.................

Boilers and engines were operated at their maximum c

New York, July 29, 1911

JEL, S. S. "ARIZONAN," Voyages 3 and 4

Steamship Company

ts, Hawaiian Island ports and return to Philadelphia,
llan out and home

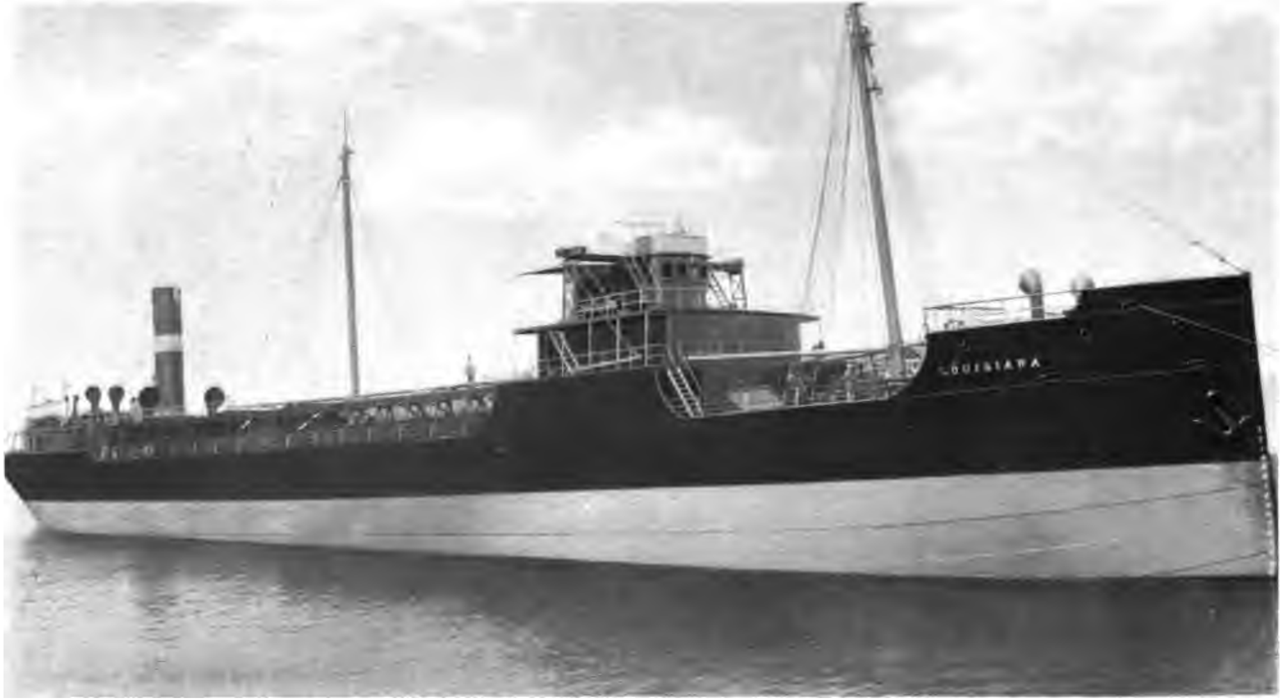
draught, 215 lbs. Pressure, Quadruple Expansion Engines

Distance Steamed	Steaming time	Round Voyage	Average Speed
30,976 miles	143 d., 8 hrs., 9 min.	186 days	9.01 knots
29,861 miles	125 d., 4 hrs., 57 min.	161 days	9.95 knots

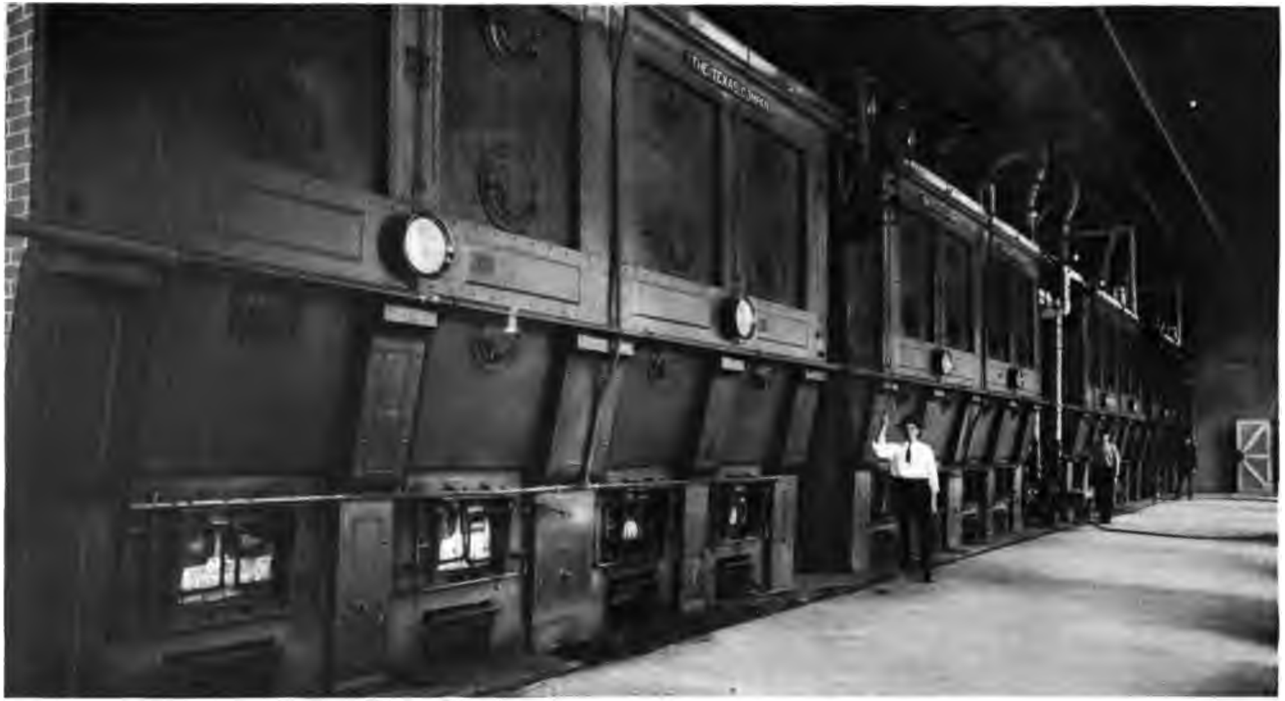
tically the same.
18 days was owing to increased speed, and 7 days used in coal-

....	$ 4,813.00
....	1,275.00
....	1,000.00
....	7,088.00
....	12,500.00

apacities on both voyages.



The Texas Company's Tank Steamship "Louisiana"



One of the Boiler-rooms of The Texas Company's Refinery at Port Arthur, Tex.

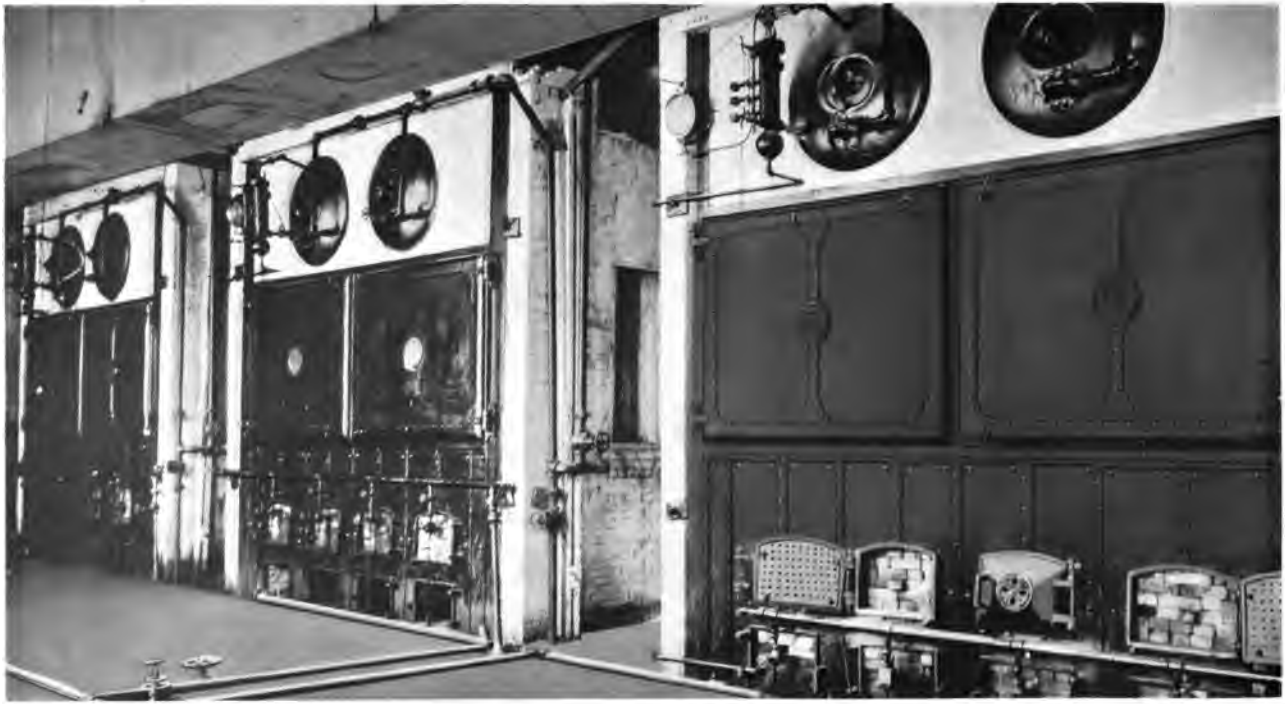
BOILER TESTS No. 1

Results of three tests on a 175 H.P. Heine water tube boiler, using Oklahoma Crude Oil of 19,580 B.T.U.'s per lb. and oil fuel of 19,330 B.T.U.'s per lb.

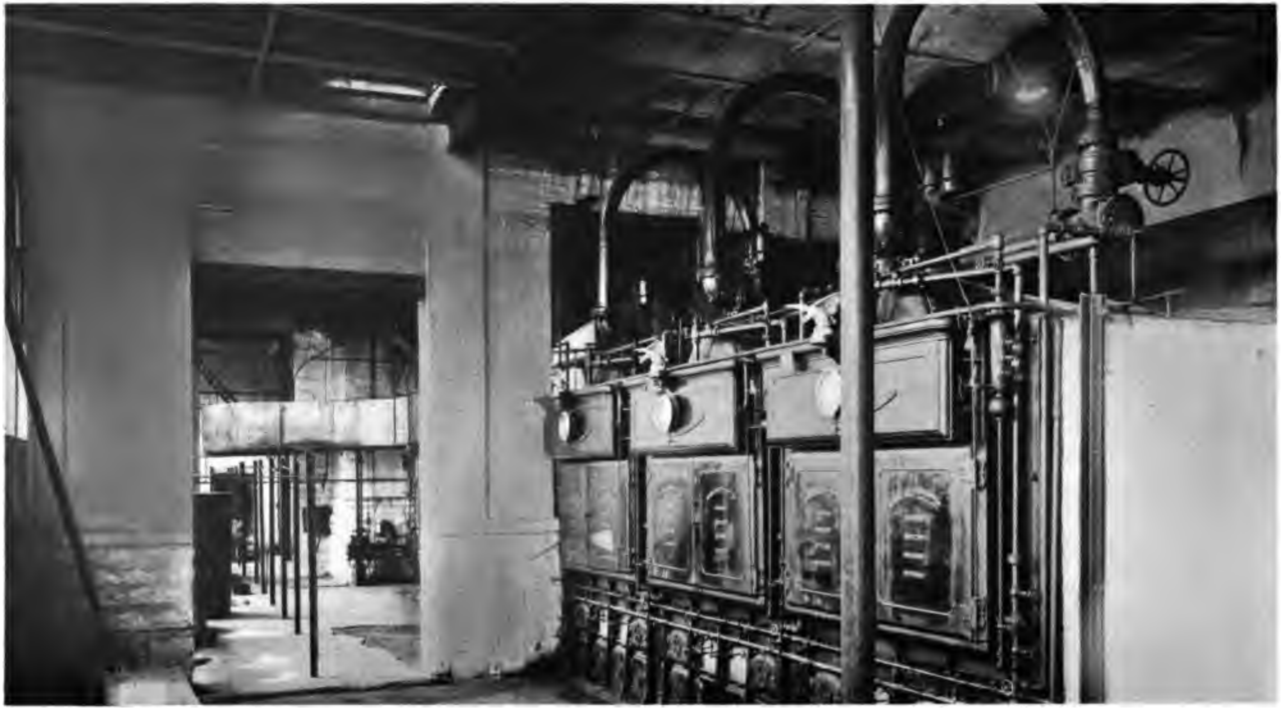
	Test No. 1.	Test No. 2.	Test No. 3.
Location	Sherman, Tex.	Sherman, Tex.	Sherman, Tex.
Date	Apr.20,'10.	Apr.24,'10.	Apr.28,'10.
Oil	Okla. Crude	Texaco Oil Fuel	Okla. Crude
Burner	S. C. T.	Hammel	Gem
Equiv. evap. from and at 212° F. per lb. of oil	15.6 lbs.	14.8 lbs.	15.3 lbs.
Oil pressure	3.5 "	40 "	4.47 "
Steam used in burners plus that required to operate oil pressure pump (when used) in % of total steam generated by boiler	3.26%	5.62%	4.15%
Temperature of flue gas	631° F.	600° F.	576° F.
Draft	.2″ water	.2″ water	.2″ water
H.P. developed	167.5	171	174
Air used through burners	462 cu. ft. min.		
Air pressure on burners	13.7 oz.		

NOTE: In Test No. 1 low pressure air was used to vaporize the oil, and the value, 3.26%, is the per cent. of total evaporation used to operate the Root air blower.

While the results are slightly in favor of the crude oil, the fact that it flashes below 75° F. makes its use quite dangerous in transportation, storage and in the furnace. Texaco Oil Fuel is perfectly safe as it does not flash at low temperature. It is to be preferred as a fuel.



Boiler-room of the Fort Worth Water-works, Fort Worth, Tex.



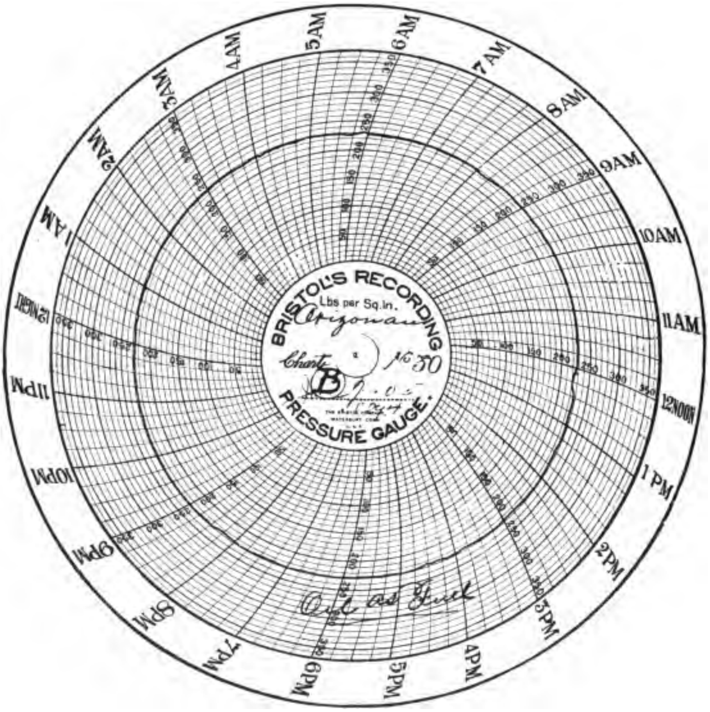
Boiler-room of the Texas Brewing Company, Fort Worth, Texas

BOILER TESTS No. 2

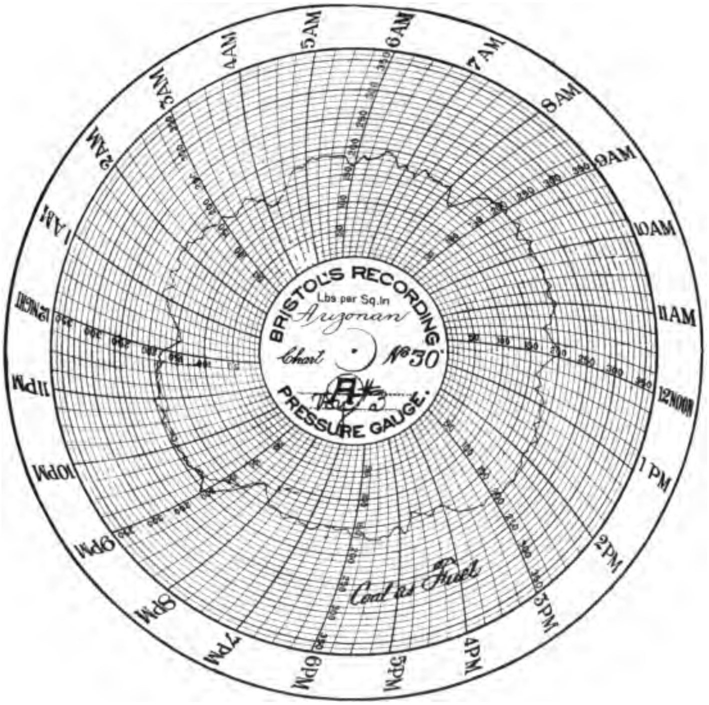
A recent comparative test between coal and oil fuel on an Aultman & Taylor 302 H.P. water tube boiler at the plant of the El Paso Smelting Works, El Paso, Texas:

	Test No. 1.	Test No. 2.	Test No. 3.
Date	Dec. 19, '10.	Dec. 20, '10.	Jan. 2, '11.
Burner	....	....	Gem
Coal	San Antonio, N. M. Run of Mine	Dawson, N. M. Lump	
Equiv. evap. from and at 212° F. per lb. of fuel as fired	7.00 lbs.	6.69 lbs.	14.76 lbs.
Temperature of flue gas	615 F.	663 F.	529 F.
Draft	.37" water	.37" water	.37" water
H. P. developed	215	226	278
Oil Pressure	....	....	6 lbs.
Ratio of steam through burners to total evaporation of boiler	....	....	4.33%
Efficiency of boiler and grate	55.2%	52.3%	75%

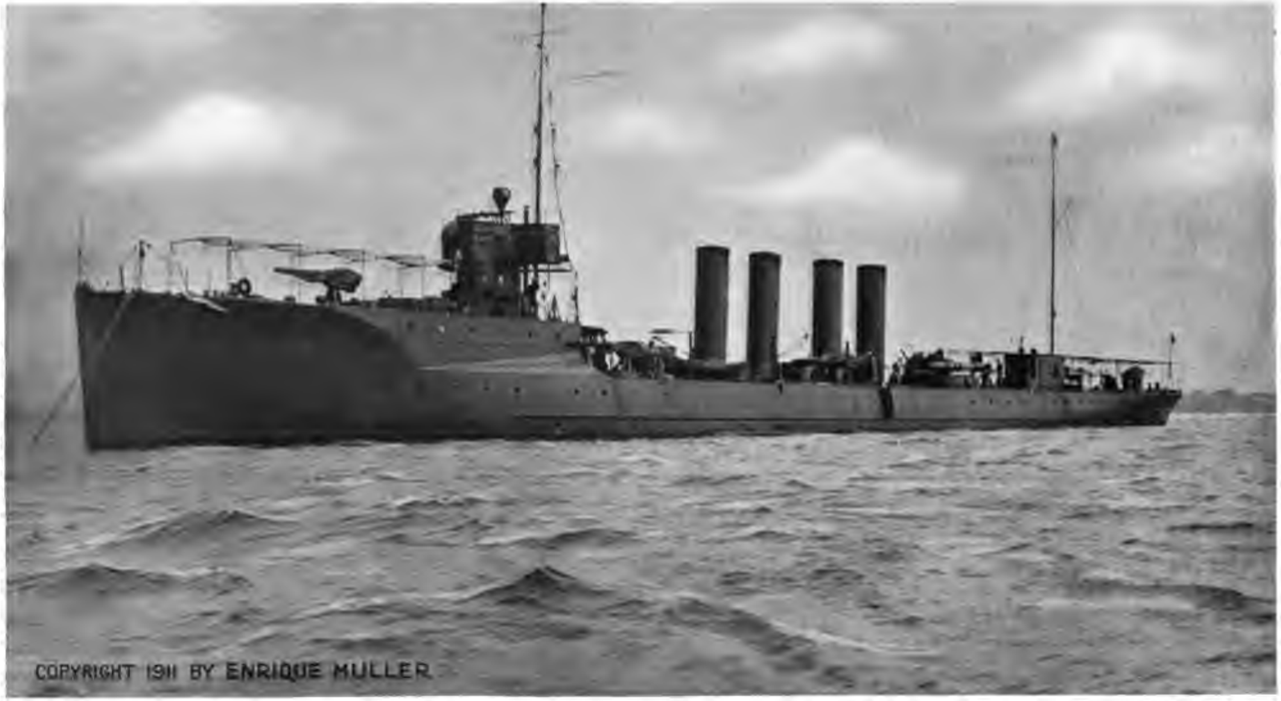
From an evaporative standpoint, these tests would indicate that 3.2 bbls. of the oil used in these tests are equivalent to 1 ton of San Antonio coal and that 3.1 bbls. of oil are equivalent to one ton of Dawson coal.



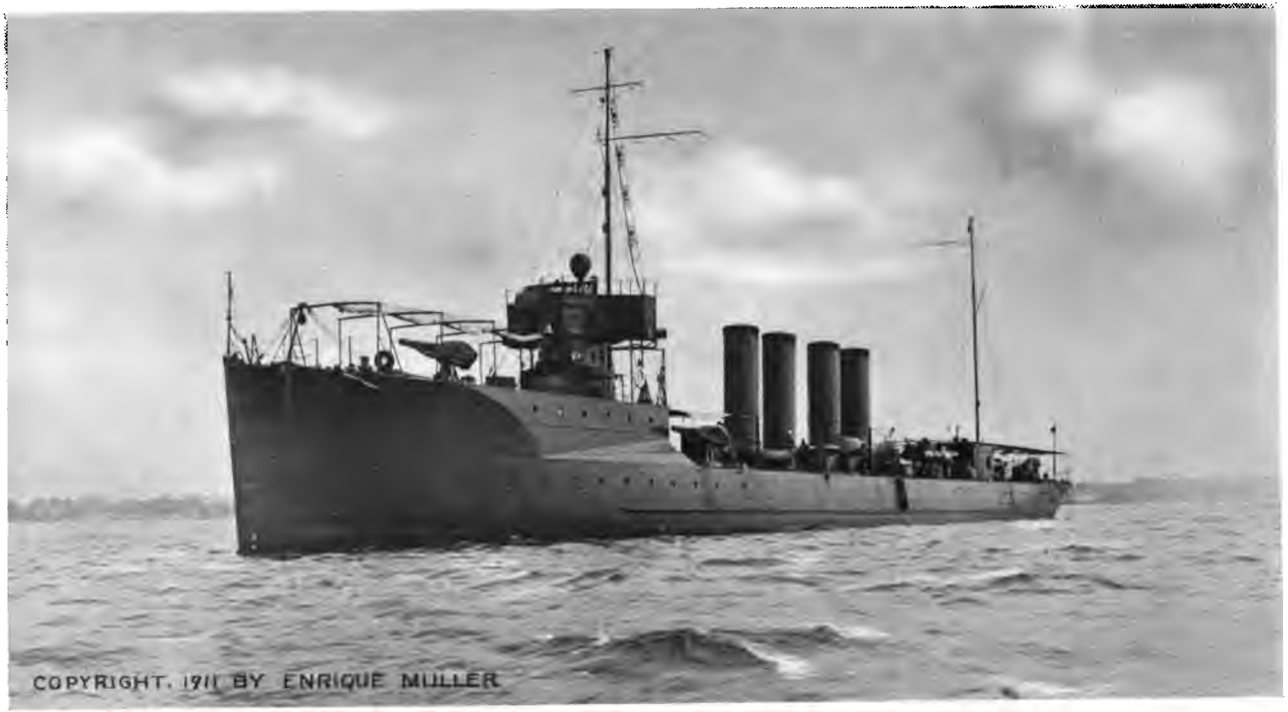
Steam Pressure Chart from S. S. Arizonan—Oil as Fuel



Steam Pressure Chart from S. S. Arizonan—Coal as Fuel



U. S. S. Drayton. Burning The Texas Company's Oil Fuel



U. S. S. Paulding. Burning The Texas Company's Oil Fuel

BOILER TEST No. 4 A (Continued)

30. Useful evaporation per lb. of oil	16.28	14.65
31. Boiler efficiency, per cent	.....	77.5
32. B. T. U. per lb. oil as fired	19,465	19,465
33. Per cent. used to evaporate water in boiler	.....	77.5
34. Per cent. lost in dry chimney gases.	11.9	14.16
35. Per cent. lost due to CO	0.0	0.0
36. Per cent. to superheat atomizing steam	.26	.44
37. Per cent. lost due to moisture of formation	6.97	7.55
38. Per cent. lost due to radiation, etc.	.....	0.35
39. Per cent. excess air	95.6	114.8
40. Temperature of Boiler Room	89.6	94.0
41. Lbs. steam for atomizing per lb. oil	.588	8.85
42. Humidity	47	43

BOILER TEST No. 4 B

Partial results of a series of tests made by Prof. E. W. Kerr, M. E. and H. A. Nadler, B. S., upon a horizontal return tubular boiler, size of boiler 18 ft. long by 72 in. in diameter, containing 80 4-in. tubes.

1. Number of test	19	20
2. Date of test	May 31	June 1
3. Duration of test (hrs)	5.0	5.0
4. Total weight of oil fired	1,800	1,713
5. Total water fed to boiler, lbs	29,395	26,625
6. Total water evaporated, lbs	29,335	26,556
7. Total equivalent evaporation, F. & A. 212°, lbs	30,350	27,550
8. Factor of evaporation	1.035	1.036
9. Oil burned per hour, lbs	360.0	342.6
10. Water actually evaporated per hour, lbs	5,867	5,311
11. Equivalent evaporation, F. & A. 212° per hr., lbs	6,070	5,510
12. Equivalent evaporation, F. & A. 212° per sq. ft., H. S. per hr., lbs.	3.46	3.13

BOILER TEST No. 4 B (Continued)

13. Steam pressure, gauge	79.5	88.8
14. Temperature feed water	210.0	209.6
15. Temperature flue gas	462.5	456.3
16. Temperature furnace	.....	.....
17. Draft, ash-pit, inches water	.025	.024
18. Draft, flue, inches water	.219	.197
19. Draft, furnace, inches water	.212	.170
20. Quality of steam, per cent. dry	99.8	99.7
21. H. P. developed	170.0	160.0
22. Per cent. of rated H. P. developed.	120.5	109.5
23. Actual evaporation per pound of oil as fired	16.30	15.5
24. Equivalent evaporation F. & A. 212° per lb. oil	16.87	16.05
25. Lbs. steam to atomize oil per hour	159	126
26. Per cent. of total steam generated, used to atomize oil	2.71	2.37
27. CO_2, per cent	8.3	8.6
28. O, per cent	10.15	9.4
29. CO, per cent	0.0	0.0
30. Useful evaporation per lb. of oil	16.4	15.68
31. Boiler efficiency, per cent	.....	78.6
32. B. T. U. per lb. oil as fired	19,465	19,465
33. Per cent. used to evaporate water in boiler	.....	78.6
34. Per cent. lost in dry chimney gases.	10.7	10.12
35. Per cent. lost due to CO	0.0	0.0
36. Per cent. used to superheat atomizing steam	.14	.13
37. Per cent. lost due to moisture of formation	6.88	6.90
38. Per cent. lost due to radiation, etc.	.....	4.25
39. Per cent. excess air	85.0	75.5
40. Temperature of Boiler Room	87.8	90.4
41. Lbs. steam for atomizing per lb. oil	.442	.368
42. Humidity	69	65

BOILER T

EVAPORATIVE TEST MADE BY THE PA

At their Redondo Plant on a 604 H.P. Babcock & Wilcox Boile

GENERAL DATA

Date of Test, (1910)		Aug. 8
Test Number	No.	1
Duration of Test	Hrs.	7
Steam Pressure	Lbs.	184.9
Steam Temperature	Deg.F.	473.3
Superheat	Deg.F.	91.8
Temperature Feed Water	Deg.F.	90.6
Factor of Evaporation	......	1.237
Average Water Level	Ins.	4
Barometer	Ins.	29.97
Temperature Boiler Room	Deg.F.	88.7
Temperature Flue Gases	Deg.F.	385.3
Draft: In Ash Pit	Ins.	.025
Draft: In Furnace	Ins.	.01
Draft: In Rear Pass	Ins.	.005
Carbon Dioxide	%	12.2
Oxygen	%	3.6
Excess Air	%	28.7
Smoke	......	None
Position of Ash Pit Doors		
Temperature in First Pass Above 3d Tube	Deg.F.	1100
Temperature Top First Pass	Deg.F.	640
Temperature Top Second Pass	Deg.F.	570
Temperature Bottom Second Pass	Deg.F.	500
Temperature Bottom Third Pass	Deg.F.	450
Total Water Actually Evaporated	Lbs.	85766
Total Water Evaporated from and at 212° F.	Lbs.	106092
Water per Hour Evaporated from and at 212° F.	Lbs.	15156
Steam used by burners: Pounds per Hour	Lbs.	234
Steam used by burners: Per cent. of Total Steam	%	1.54
Steam Pressure to Burners	Lbs.	48.2
Oil Pressure to Burners	Lbs.	11.4
Temperature Oil to Burner Line	Deg.F.	131.3
Kind of Oil Burned		
Specific Gravity of Oil at 60° F.	S. G.	.9770
Specific Gravity of Oil, Beaume at 60° F	S. G.	13.3
Moisture in Oil	%	.4
Heat Value of Oil as Fired	B.T.U.	18280
Heat Value of Oil Corrected	B.T.U.	18353
Total Oil as Fired	Lbs.	6913
Total Oil Corrected for Moisture	Lbs.	6885
Oil Per Hour as Fired	Lbs.	987
Oil Per Hour Corrected	Lbs.	983
Water Evaporated F. & A. 212° F. Per Sq. F. H. S.	Lbs.	2.58
Boiler Horse Power Builders' Rating	B.H.P.	604.
Boiler Horse Power Developed	B.H.P.	439.3
Per cent. Builders' Rating	%	72.7
Water Evap. Per Lb. of Oil from and at 212° F.: Oil as Fired	Lbs.	15.35
Water Evap. Per Lb. of Oil from and at 212° F.: Corrected for Moisture	Lbs.	15.41
Boiler Efficiency	%	81.1

NOTE: All tests were under the direction of Frank T. Clarke, for the Power Com
Six of the above tests were conducted in six consecutive days.
The Boiler used for testing was No. 1, in Battery No. 1, Erected 1906

TEST No. 5

PACIFIC LIGHT & POWER CORPORATION

ler being on test but serving usual electric generative apparatus.

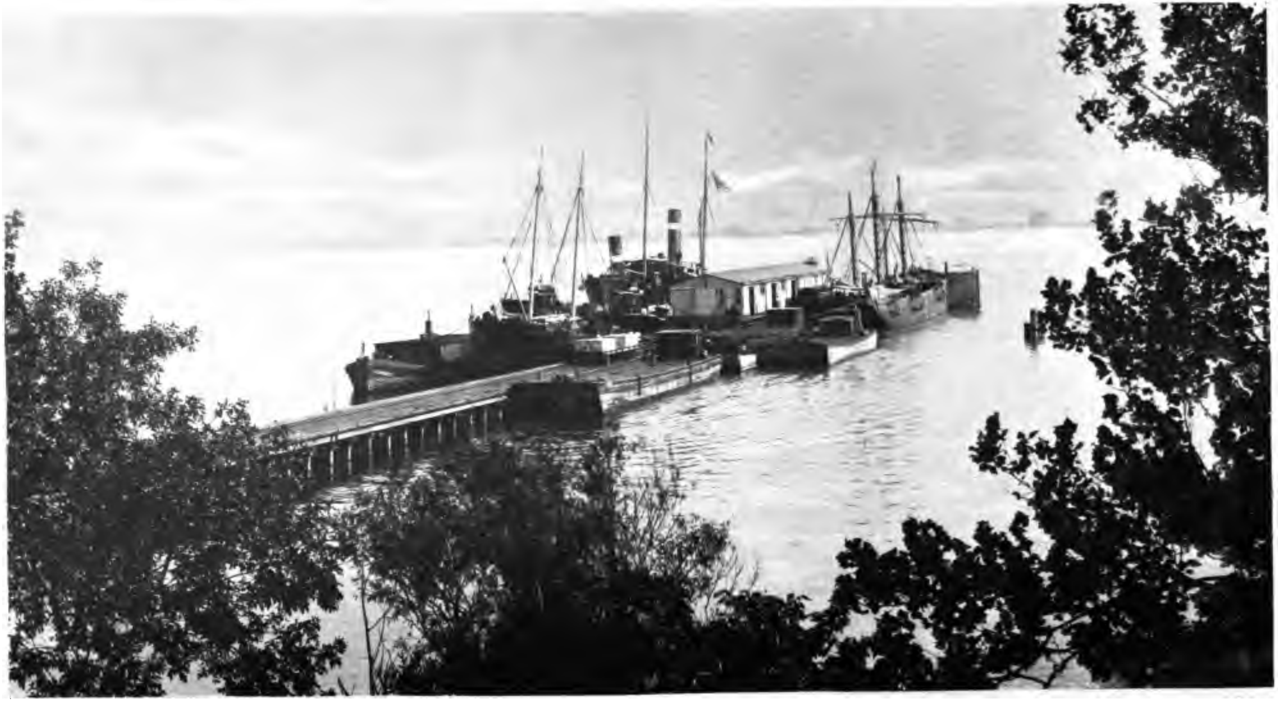
AND RESULTS Courtesy of Pacific Light and Power Company. 5-12-11.

Aug. 9	Aug. 10	Aug. 11	Aug. 12	Aug. 13	Sept. 5	Average of all Tests
2	3	4	5	6	7	
7	7	7	7	7	7	7
184.9	186.0	184.7	183.5	184.6	184.9	184.8
457.4	468.8	465.1	473.8	493.8	526.7	479.8
76.0	86.9	83.7	93.0	112.5	144.3	98.3
92.6	92.7	93.4	90.8	94.6	101.2	93.7
1.225	1.232	1.229	1.237	1.245	1.259	1.238
4	4	4	4	4	4	4
30.00	30.00	30.09	30.08	30.04	29.68	29.97
86.6	84.4	85.2	87.3	86.7	84.4	86.2
397.5	409.1	406.2	429.0	477.1	537.5	434.5
.035	.055	.044	.071	.127	.230	.084
.005	.025	.014	.060	.130	.188	.062
.014	.061	.046	.133	.296	.471	.147
13.4	13.3	14.3	14.2	13.3	12.1	13.2
2.7	2.4	1.8	1.7	2.8	6.8	3.1
17.7	18.5	10.6	11.3	18.5	43.0	21.2
None	None	None	None	None	Lt. Haze	
Doors Wide Open Throughout All Tests.						
1090	1160	1180	1240	1300	1600	1240
640	700	680	780	940	1170	793
540	620	610	650	740	820	650
500	520	510	550	600	700	554
450	505	495	530	570	660	523
111988	129628	129609	156622	191290	226558	147351
137185	159702	159289	193741	238156	285236	182771
19598	22814	22756	27677	34022	40748	26110
441	549	549	624	708	873	568
2.25	2.40	2.40	2.25	2.08	2.13	2.15
74.7	99.7	102.6	120.4	142.5	167.6	122.2
15.2	24.4	25.4	38.3	46.1	61.6	31.6
134.3	133.5	142.3	140.1	142.1	141.7	137.9
Oil from Los Angeles Fields.						
.9770	.9763	.9770	.9776	.9776	.9797	.9776
13.3	13.4	13.3	13.2	13.2	12.9	13.2
.5	.45	.4	.8	.65	.6	.54
18256	18131	18253	18214	18171	17985	18184
18347	18212	18326	18357	18289	18093	18281
8758	10322	10115	12602	16580	20205	12213
8714	10276	10075	12501	16472	20084	12144
1251	1474	1445	1800	2369	2887	1745
1245	1467	1439	1786	2353	2869	1735
3.24	3.78	3.77	4.58	5.63	6.74	4.32
604.	604.	604.	604.	604.	604.	604.
568.0	661.3	659.6	802.2	986.2	1181.0	756.8
94.0	109.4	109.2	132.8	163.3	195.5	125.3
15.66	15.47	15.75	15.37	14.37	14.12	15.15
15.74	15.54	15.81	15.49	14.46	14.20	15.23
82.8	82.4	83.3	81.5	76.4	75.8	80.47

pany.

Boiler Heating Surface
6,042 Square Feet.

Oil Tested by New York Testing
Laboratory, Los Angeles Branch.



Terminal of The Texas Company at Delaware River

Antwerp Terminal. The Texas Company

Antwerp Terminal. The Texas Company

BOILER

COMPARATIVE RESULTS OF TES
STIRLING WATER-T

The Babcock & Wilcox boiler was equipped with a furnace having burners
Stirling boiler was equipped with burners inserted through the fire doors and dir
The tests were made at the Pacific Light & Power Corporations, 3d St. P
Company, Mr. E. H. Peabody of The Babcock & Wilcox Company, and Prof. C.

GENERAL DAT

NAME OF BOILER			Babcock & Wilcox
Date of Test, 1903			Dec. 4
Duration of Test		Hrs.	10
Steam Pressure		Lbs.	156.4
Temperature of Feed Water		F°	62.65
Factor of Evaporation			1.2050
Pressure of Oil		Lbs.	36
Temperature of Oil		F°	109½
Temperature of Air in Fire Room		F°	87½
Temperature of Escaping Gases		F°	438
Draft	In Flue outside damper	Ins.	....
	Near Damper, boiler side	Ins.	.08
	In Furnace	Ins.	.02
Per cent. moisture in steam		%	0.21
			Start Fin
Water level before putting out fires		Ins.	5¾ 6¾
Water level after fires were out 3 minutes		Ins.	5¼ 6
Drop in water level on putting fires out		Ins.	½ ¾
Maximum water level during test		Ins.	... 7
Minimum water level during test		Ins.	... 4
Average level during test	Inches above bottom of glass	Ins.	... 5¾
	Inches above or below center glass	Ins.	¾ above
Total water apparently evaporated		Lbs.	152850
Total water corrected for moisture in steam		Lbs.	152529
Total water evaporated into dry steam from and at 212°		Lbs.	183797
Water per hour evaporated into dry steam from and at 212°		Lbs.	18380
Steam used by burners	Pounds per hour	Lbs.	342.6
	Per cent. of steam generated	%	1.96
Kind of oil burned			Wh
Specific gravity of oil, 60° F		S. G.	.9417
Specific gravity of oil by Beaume scale		Deg.	19.05
Per cent. of moisture in oil		%	1.06
Heat value of oil as fired, B. T. U. per lb		......	18428.4
Heat value of oil, corrected for moisture		......	18626
Total oil, as fired		Lbs.	11597.5
Total oil, corrected for moisture		Lbs.	11474.6
Oil per hour, as fired		Lbs.	1160
Oil per hour, corrected for moisture		Lbs.	1147
Water evaporated per sq. ft. of heating surface, from and at 212° per hour	Com'tee measurem't	Lbs.	3.85
	Builder's specification	Lbs.	3.94
Horse-power developed		H. P.	532.7
Per cent. above committee's rating		%	11.69
Per cent. above builder's rating		%	14.08
Water evaporated per lb. of oil from and at 212° F.	Oil as fired	Lbs.	15.849
	Corrected for moisture	Lbs.	16.02
Efficiency		%	83.06

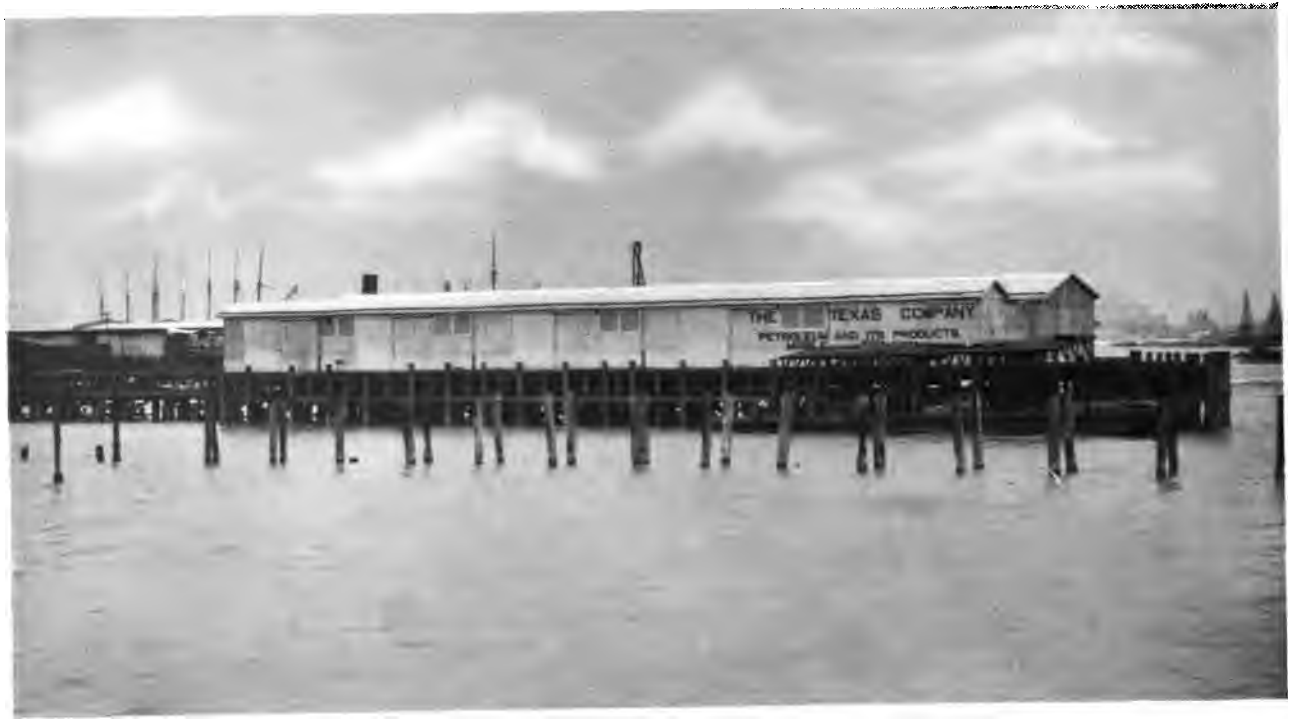
TEST No. 6

ESTS ON BABCOCK & WILCOX AND
TUBE STEAM BOILERS

ers located at the bridge wall and discharging flame toward front of the boiler. The
directing flame toward the bridge wall in accordance with the usual practice.
Plant, Los Angeles, Cal., by a committee consisting of Mr. H. M. Boone of the Stirling
C.L. Cory of University of California.

ATA AND RESULTS.

Stirling	Stirling	Babcock & Wilcox	Babcock & Wilcox	Stirling	Stirling	Babcock & Wilcox
Dec. 5	Dec. 7	Dec. 8	Dec. 16	Dec. 17	Dec. 19	Dec. 21
10	10	10	10	10	10	10
156.0	156.4	156.2	156.9	157.0	156.3	157.3
63.65	63.70	62.54	61.10	62.0	62.05	60.92
1.2039	1.2039	1.2051	1.2067	1.2058	1.2056	1.2070
25	32	50	46	63	60	55
88	85	124	132	128	104½	111
95½	100	94	100	101½	105	103
454	517	464	525	606	720	622
....	....	....	....	....	.66	.49
.14	.20	.15	.29	.25	.34	.49
.09	.15	.05	.12	.13	.15	.15
0.56	0.52	0.14	0.16	0.58	0.69	0.14
Start Fin.	Start Fin.	Start Fin.	Start Fin.	Start Fin.	Start Fin.	Start Fin.
7⅜ 6⅝	10½ 13	6¾ 7¾	5¾ 5½	10½ 13¾	13 11¼	5¾ 6⅛
5 3⅝	6¾ 8¾	6⅛ 7⅛	4 4	1 8	⅜ ¼	4¾ 4⅛
2⅜ 3	3¾ 4¼	⅝ ⅝	1¾ 1½	9½ 5⅜	12⅝ 11	1 2
7⅜	13	7¾	6¼	13¾	13	10
2	3½	5	4	1	¼	4⅛
5⅛	5½	6⅝	5¼	8	6⅛	6¼
1⅞ below	1½ below	1⅝ above	¼ above	1 above	⅞ below	1¼ above
98272	124896	179233	232113	155682	190513	281030
97722	124247	178982	231742	154779	189198	281236
117648	149581	215691	279643	186633	228097	339452
11765	14958	21569	27964	18663	22810	33945
383.7	387.7	479.8	604.0	444.4	456.8	688.0
3.42	2.72	2.33	2.27	2.50	2.10	2.13
Whittier	Mixture of Whittier and Los Angeles				Whittier	
.9430	.9530	.9529	.9637	.9629	.9410	.9407
18.83	17.17	17.18	15.48	15.60	19.17	19.22
1.06	4.93	4.62	8.71	8.82	.74	.42
18478.8	17791.2	17887.5	16904.7	16956.0	18567.0	18578.7
18677	18714	18754	18518	18596	18705	18657
7764.0	10577.0	14441.5	20127.0	14361.5	16585.5	23966.5
7681.7	10055.7	13774.3	18373.9	13094.8	16462.8	23865.8
776	1058	1444	2013	1436	1659	2397
768	1006	1377	1837	1309	1646	2387
3.58	4.55	4.52	5.86	5.68	6.94	7.11
3.52	4.47	4.62	5.99	5.58	6.82	7.27
341.0	433.6	625.2	810.6	541.0	661.2	983.9
3.65	31.78	31.07	69.93	64.43	100.96	106.27
1.79	29.42	33.87	73.57	61.48	97.36	110.69
15.153	14.142	14.936	13.894	12.995	13.753	14.164
15.31	14.87	15.66	15.22	14.26	13.85	14.22
79.16	76.73	80.64	79.37	74.05	71.50	73.62



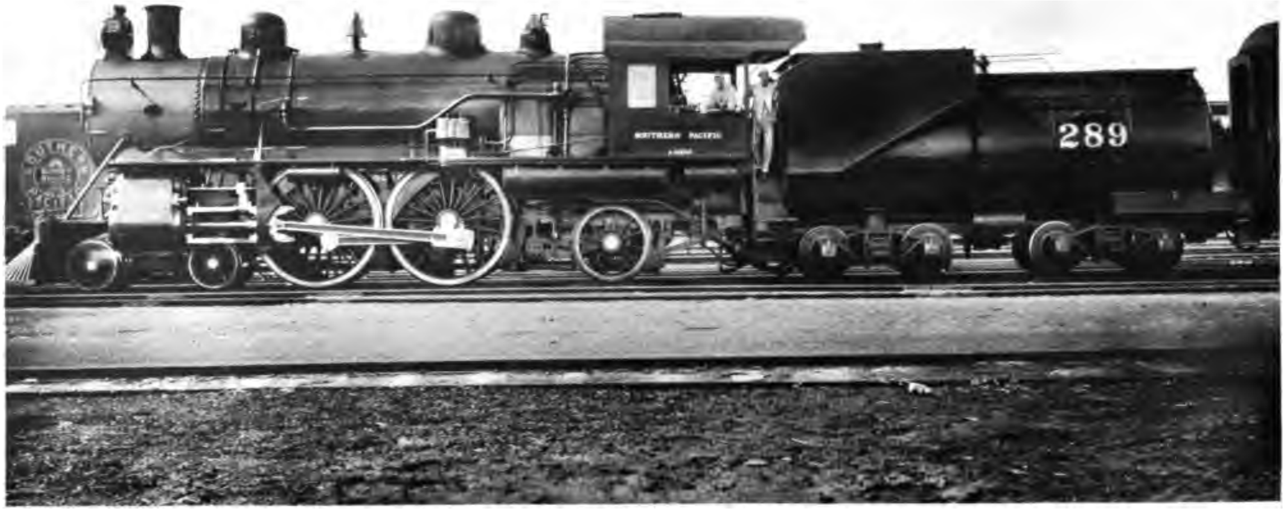
Terminal of The Texas Company at Mobile, Ala.

BOILER TEST No. 6

SUMMARY OF PRINCIPAL RESULTS

Courtesy of Pacific Light and Power Company. 5-11-11.

TEST	BOILER	Rate of Evaporation	Horse Power	Per cent. Above Builders' Rating	Per cent. Moisture in Steam	Temperature of Escaping Gases	Evaporation per lb. of oil from and at 212°	Per cent. Steam used by Burners	Efficiency	Per cent. Gain in Efficiency B.&W. over Stirling
1st Test....	Babcock & Wilcox	3.85	532.7	14.1	0.21	438	16.02	1.96	83.06	4.93
1st Test....	Stirling..........	3.58	341.0	1.8	0.56	454	15.31	3.42	79.16	....
2d Test.....	Babcock & Wilcox	4.52	625.2	33.9	0.14	464	15.66	2.33	80.64	5.10
2d Test.....	Stirling..........	4.55	433.6	29.4	0.52	517	14.87	2.72	76.73	....
3d Test.....	Babcock & Wilcox	5.86	810.6	73.6	0.16	525	15.22	2.27	79.37	7.18
3d Test.....	Stirling..........	5.68	541.0	61.5	0.58	606	14.26	2.50	74.05	....
Cap'ty Test.	Babcock & Wilcox	7.11	983.9	110.7	0.14	622	14.22	2.13	73.62	2.97
Cap'ty Test.	Stirling.........	6.94	661.2	97.4	0.60	720	13.85	2.10	71.50	....



Oil-burning Locomotive, Southern Pacific R. R.

LOCOMOTIVE DATA

I. & G. N. R. R.

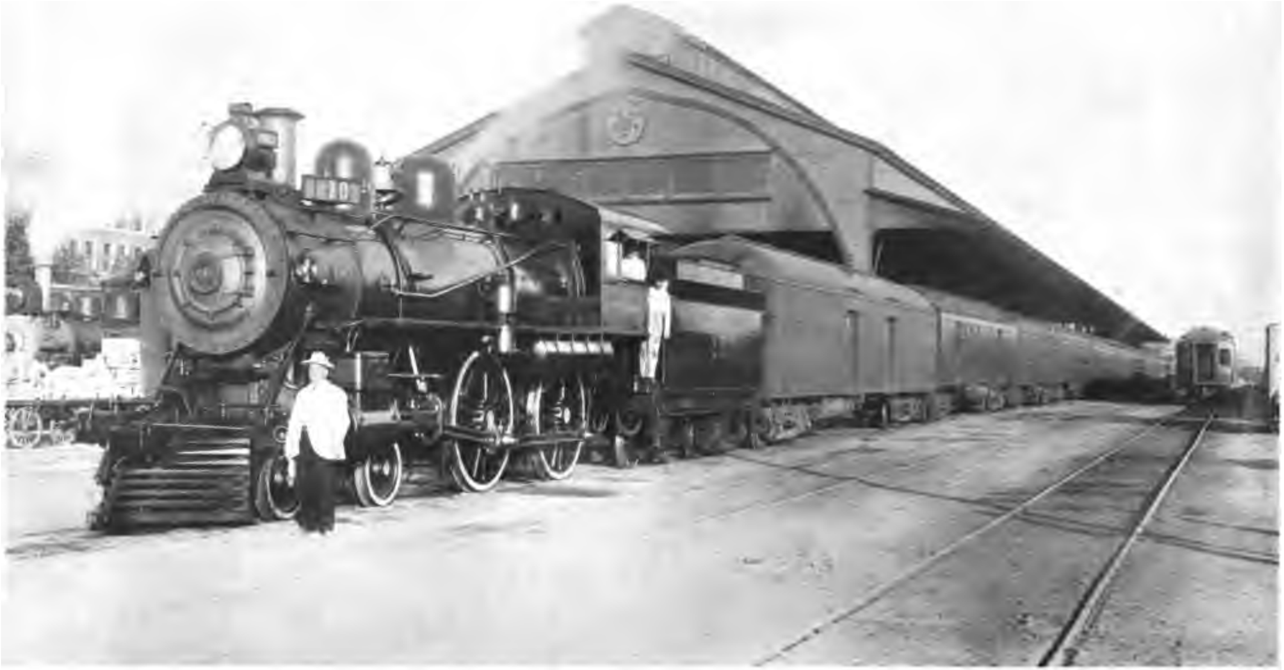
A summary of results for a period of 8½ years, in both freight and passenger service: 1902–1910.

Passenger Service.

Bbls. Oil Fuel	Bbls. Oil Fuel to ton coal used by passenger engine	Tons of Fuel	Cost Fuel for passenger trains	Cost per ton of coal	Miles Coal burner per engine	Cost per bbl.	Miles oil burner per engine	Cost of oil fuel equal of ton coal in passenger service	Engine mile to ton of coal	Engine mile to bbl. of oil
Coal		395,660	1,150,234.87	2.94	9,453,822	. . .	. . . . . .	. . .	23.9	. . .
Oil	. . . .									
729,305	3.68	197,622	442,665.33	. . .	. . . .	.609	4,738,563	2.23	. . .	6.5

I. & G. N. R. R. Freight Service.

Bbls. Oil Fuel	Bbls. Oil Fuel to ton of coal freight engines	Tons of Fuel	Cost of Fuel for freight trains	Cost per ton of coal	Miles Coal burner freight engine	Cost per bbl.	Miles Oil burner freight engine	Cost of oil fuel equal of ton coal in freight service	Engine mile to ton of coal	Engine mile to bbl. of oil
Coal		923,964	2,712,258.46	2.94	12,992,249	. . .	. . . .	. . .	14.06	. . .
Oil										
1,450,691	3.91	369,920	885,214.34	. . .	. . . .	.61	5,325,408	2.39	. . .	3.67



Oil-burning Locomotive. Sunset Limited Southern Pacific R. R.

LOCOMOTIVE DATA

Results of a comparative test on the I. & G. N. Railroad in 1903. Each engine made practically the same mileage and hauled the same tonnage as the other.

Regular freight run between Houston and Palestine:

OIL BURNER.

Miles Run	Bbls. Oil Consumed	Cost of Oil	Cost per Mile
3624	760.5	$458.58	.1265

COAL BURNER.

Miles Run	Tons of Coal Consumed	Cost of Coal	Cost per Mile
3622	195	$569.40	.1572

Cost indicated does not include the labor of handling the fuel, cleaning fire-boxes, etc.

Terminal of The Texas Company at Delaware River

DETERMINATION OF THE MOST ECONOMICAL FUEL

In every power plant the fuel bill is perhaps the largest single item of expense confronting the manager or superintendent.

In selecting a fuel which will be the most economical for any particular service, there are a number of points to be considered other than the comparative price per ton of coal, per barrel of oil or per 1,000 cubic feet of gas, as the case may be. Some of the most important of these points are:

Reliability of Supply.

Is the plant operation liable to suffer on account of a scarcity of fuel due to strikes, lack of cars, increased demand, cold weather, etc.?

Will the supply of fuel be uniform in quality?

Is it advisable to provide a large storage space and carry a supply of coal sufficient to tide over any possible scarcity, and, if so, what is the loss due to exposure?

Is the company from which fuel is purchased in a position to carry out its contract?

Operation.

Will the same careful attention to the fires be obtained with one fuel as with another, under all conditions of weather?

What will be the comparative labor cost of handling each fuel?

Is the elimination of smoke, dirt and storage space an item to be considered at this plant?

Will a reduction in boiler stresses and a uniform steam pressure be productive of more economy of operation and maintenance?

What fuel will most readily adapt itself to sudden demands for power?

Money Value.

Giving due consideration to the existing equipment and the peculiar requirements of the plant, what is the comparative money value of the several available fuels?

Barrels of Oil Equivalent to a Ton of Coal.

This is almost invariably the first question the prospective user of oil asks when contemplating a change from coal to oil, and it is a question often difficult to answer.

Coal varies in quality over a wide range, from the high priced anthracite and bituminous coals of the East to the low grade lignites of the Middle West, while the quality and heating value of the oil varies within narrow limits. Thus it would seem that the only fair comparison would be in actual test for a particular installation and coal.

This comparison of fuels under test conditions brings in another factor often overlooked but which will be self-evident to the engineer. When burning coal in the furnace of a boiler, the economical use of that fuel is dependent in a great measure on hard work, skill, and close attention to firing, on the part of the fireman. A lazy fireman, in order to save physical exertion, can easily and does waste by improper firing, 10 to 20 per cent. of the coal fired, and when the conditions existing in the average boiler room (where coal is used as fuel) are considered, the desire to sidestep physical exertion cannot perhaps be wondered at.

When a boiler efficiency test is being run, however, how different things are; the very best firemen available are pressed into service, and are kept on the jump doing their utmost to keep the efficiency at a high and unnatural mark. When the test is over and the report on "the excellent work our boilers are doing" has been made, things fall back into the same old operating routine, and boiler efficiency becomes normally low again.

Compare the foregoing with the conditions existing in boiler rooms where oil fuel is used. No physical exertion is required, as in the case of firing coal, and the fireman becomes a boiler operator, with ample time to make oil burner and feed water adjustments and to watch closely the operation of the boiler plant, instead of being a coal and ash shoveler, with little or no time nor disposition to do anything more.

Using oil under boilers requires no exertion, physical or mental, on the part of the boiler operator, and as a result he can and will maintain his boiler efficiency at the same high mark month after month just as though he were running a continuous efficiency test.

In burning oil, test conditions are every-day conditions. This cannot be said of coal. Hence the comparative test results are often misleading.

Knowing the average daily evaporation per pound of coal, and per pound of oil, *as fired*, which means as purchased, the comparison is readily obtained, as far as actual combustion is concerned. This does not take into account the many advantages of the liquid fuel outlined on page 10.

Assume the average evaporation from and at 212° F. per pound of coal as fired to be 7 lbs., and for oil 15 lbs. (these figures will cover the average case); then the ratio of evaporation is as 7 is to 15 and the pounds of oil equivalent to 2000 lbs. of coal will be 7:15::x:2000, or x = 933 lbs.; which, divided by 314 lbs. per barrel equals 2.97 bbls. oil equivalent to one ton of coal.

INCREASED CAPACITY OF COAL BURNING PLANTS WHEN USING OIL FUEL

No exact formulæ for the height of stacks for oil burning furnaces are available, but general experience has proven that for a given installation about 60% of the height of a stack for a coal burning furnace will give satisfactory results when burning oil.

The reason for this is obvious, as the air supporting combustion in a coal burning furnace is retarded by the bed of coals and clinkers, necessitating a greater draft than is necessary for oil. Hence the stack capacity for a coal burning installation will be materially increased if oil fuel be used.

This increased capacity applies not alone to the stack, but to the boilers as well. The absence of soot on the boiler shell and tubes, — decreased losses in the flue gas, as well as a material reduction in stand-by losses all tend to increase the capacity of the plant as a whole when burning oil.

The sum total of these savings often amounts to 20% to 30%, and should be given careful consideration by those wishing to increase their plant capacity without providing additional boilers, stack or space.

Effect of an Excessive Draft when Using Oil Fuel.

In general a draft pressure of .15″ to 2″ of water gives the best results when using oil fuel. When greater differences of pressure exist between the furnace and boiler room it is difficult to so design the furnace as to prevent some of the air supporting combustion from passing by the fire, thus doing no good as far as the combustion is concerned, but tending to cool the gases, lower the CO_2, and increase the per cent. of excess air, all of which will lower the efficiency of the boiler and furnace.

EFFECT OF BURNING CARBON TO CARBON MONOXIDE

With the requisite amount of air for combustion 1 lb. of carbon burned to carbon dioxide liberates 14,600 B.T.U.

With restricted air supply 1 lb. of carbon burned to carbon monoxide liberates 4,450 B.T.U.

If the draft is sufficiently restricted to cause the carbon to be burned to carbon monoxide instead of to carbon dioxide, the above difference of 10,150 B.T.U. per pound of carbon is lost by the passing of this combustible gas up the stack.

Owing to the impossibility of closely regulating the air supply in most coal burning furnaces and to the necessary restriction of air supply to meet increases in steam pressure, there will many times be an action taking place similar to that in a gas producer with the formation of CO due to insufficient air supply. Every pound of carbon burned to CO represents a heat loss of 10,150 B.T.U.

This action is not present in the oil burning furnaces to an appreciable extent, as the supply of air and oil can be properly controlled at all times.

COAL

Weathering of Coal.

Experiments of S. W. Parr and N. D. Hamilton (Bulletin No. 17 of University of Illinois, Eng'g Experiment Station, 1907).

1. That outdoor exposure results in a loss of heating value varying from 2 to 10 per cent.
2. Dry storage has no advantage over storage in the open except with high sulphur coals.
3. In most cases the losses in storage appear to be practically complete at the end of five months.

EFFECTIVE THERMAL VALUE OF LIGNITES

Some excellent grades of lignite as purchased at the mine, at mine weights, contain as high as 40 per cent., by weight, of moisture (water). If a pound of such lignite is dried (that is, all of the moisture expelled), only 6–10 of a pound of lignite will be left and available for use as a fuel.

A pound of this *dried* lignite may contain as high as 10,500 B. T. U., but since each pound as originally purchased at the mine contained only 6–10 of a pound of lignite and 4–10 of a pound of water in saturation, it is evident that a pound of such lignite as purchased contained 6–10 of 10,500, or only 6,300 B. T. U.

This 6,300 B. T. U. value is reduced by the heat required to evaporate and superheat the moisture present in the lignite when fired in a boiler furnace. Assuming the lignite to contain when fired 25 per cent. of moisture (the difference between 25 per cent. and 40 per cent. having been evaporated in transit), then there will be required to evaporate and superheat 25-100 of a pound of moisture, 312 B. T. U., which deducted from 6,300 leaves 5,988 as the effective B. T. U. value of one pound of such lignite as purchased, when used under boilers.

Little is generally known of these characteristics of lignite fuel, and many misleading reports of analyses and B. T. U. values of *dried* lignite are published, which make no comments on the difference between lignite as purchased, as fired under boilers, and as artificially dried for analytical purposes. We accordingly deem it advisable to call the attention of our readers to these, in order that those comparing the efficiencies of lignite and oil fuel when burned under boilers can secure, from those mining and selling lignites, a correct statement of the actual heat value of a pound of such lignite as purchased at the mine, instead of basing their comparisons on B. T. U. values as published from time to time.

Analysis of San Antonio and Dawson Coal.

	San Antonio, N. M.	Dawson, N. M.
Kind of Coal	Bituminous	Bituminous
Size	Run of Mine	Lump
Fixed Carbon, %	43.01	47.7
Volatile Matter, %	38.7	35.77
Moisture, %	2.38	1.47
Ash, of dry coal, %	15.91	15.06
B.T.U. per lb. dry coal	12,629	12,632

Heat Value of Western Coal.

Table showing heat value per pound of some Western coals as purchased by consumer (deduced from Poole's Calorific Value of Fuels):

Name and Location	B.T.U. per 1 lb. coal	Theoretical evaporative power from and at 212° F.	Evaporation in Practice based on boiler and grate efficiency of 65%
Indian Territory.			
Atoka Co.	9,144	9.47	6.12 lbs.
C.O.& G.Ry.Co. (Slack).	10,319	10.63	6.91 “
Inola Strip	9,458	9.74	6.33 “
McAlester Slack	10,133	10.4	6.76 “
“ Washed Slack	10,539	10.86	7.06 “
Osage C.&M. Co., Krebs Lump	12,502	12.88	8.37 “
New Mexico.			
Location Unknown	11,741	12.00	7.86 “

Heat Value of Western Lignites (per pound of combustible).

Tests of U. S. Geological Survey, 1904-06 (Kent)
Average of Samples taken at Mine

	Fixed C. %	B.T.U. per lb. of Combustible.	B.T.U. available in the furnace (with 25% deduced from original data)
New Mexico	50.5 to 47	12,500 to 12,300	9063 to 8913
Colorado	46.	11,500	8312
Texas	44.5 to 34	11,000 to 10,900	9863 to 7938

NOTE:—Lignite contains from 30% to 40% of moisture at the mine and from 20% to 30% of moisture as fired. The values as given for 25% moisture take into account the heating of this moisture from 70° F. to 500° F. (the latter figure being the temperature of the flue gases) hence, the heating value will represent the available B.T.U. in the furnace.

High Ash Content in Texas and New Mexico Coal.

(Kent)

Locality	Moisture %	Fixed C. %	Ash %
Eagle Mine, Tex.	3.54	50.69	14.93
Sabinas Field, Vein I, Tex.	1.91	62.71	15.35
" " " II, "	1.37	68.18	13.02
" " " III, "	.84	50.18	19.63
" " " IV, "	.45	45.75	29.10

SOME EASTERN COALS

(Deduced from Calorific Power of Fuels, Poole)

	Fixed Carbon	Volatile Matter	B.T.U. per lb. Combustible	B.T.U. per lb. of Coal
Pennsylvania (Anthracite).				
Average of 21 samples	84.25%	5.62	14113	12685
Pennsylvania (Bituminous).				
Average of 28 samples	51.17%	34.04	14948	13634
Ohio.				
Average of 17 samples	51.56%	36.14	14397	12626
Kentucky.				
Vanderpool (Lump)	56.9%	35.5	14400	13306
Illinois.				
Danville	46.4%	37.1	13403	11191
Ladd (Lump)	48.2%	36.7	14700	12480
Peoria	49.21%	36.13	13323	11370
Vulcan (Nut)	45.10%	30.9	12435	9051
West Virginia.				
Pocahontas (Run of Mine)	73.65%	18.30	15682	14419
Kansas.				
Leavenworth (Lump)	43.39%	30.35	11009	8118

Lubricating Oil Storage Tanks at The Texas Company's Delaware River Terminal

HEATING VALUE OF WOOD

The heating value of perfectly dry wood is very nearly the same for the various specimens. Each contains approximately 50% of carbon. Hardwood gives a little less heat per pound than soft wood.

Newly felled wood contains from 30% to 50% of moisture, a fair average being 40%, and after eight to ten months ordinary drying in the air, this percentage of moisture is reduced to approximately 20% to 25%.

The average heating value of perfectly dry wood is about 8500 B.T.U. per pound, which will be reduced to about 6000 B.T.U. per pound for wood containing 25% moisture and to about 4600 B.T.U. per pound for 40% moisture, the last two heating values allowing for the evaporation and superheating of the moisture from 70 deg. F. to 500 deg. F.

The following table gives the average weight per cord of 128 cu. ft. for various woods, thoroughly air-dried, and the corresponding equivalent pounds of oil per cord of dry, 25% moisture and 40% moisture wood. The computations are based upon 45% boiler and grate efficiency when burning wood, and oil with an evaporative power of 15 lbs. of water from and at 212 deg. F. per pound of oil. The oil weighs 314 lbs. per barrel.

TABLE

Wood	Specific Gravity	Pounds in 1 cord of 128 cu. ft.	Bbls. Oil Equiv. to 1 cord dry	Bbls. Oil Equiv. to 1 cord 25% Moisture	Bbls. Oil Equiv. to 1 cord 40% Moisture
Hickory, shell-bark	1.000	4469	3.74	2.63	2.23
Oak, chestnut	.885	3955	3.31	2.33	1.79
Oak, white	.885	3821	3.2	2.26	1.73
Ash, white	.772	3450	2.89	2.04	1.56
Dogwood	.815	3643	3.05	2.15	1.65
Oak, black	.728	3254	2.72	1.92	1.47
Oak, Red	.728	3254	2.72	1.92	1.47
Beech, white	.724	3236	2.71	1.91	1.46
Walnut, black	.681	3044	2.55	1.80	1.38
Maple, hard (sugar)	.644	2878	2.41	1.70	1.30
Cedar, red	.565	2525	2.11	1.49	1.14
Magnolia	.605	2704	2.26	1.60	1.23
Maple, soft	.597	2668	2.23	1.57	1.21
Pine, yellow	.551	2463	2.06	1.45	1.11
Sycamore	.535	2391	2.00	1.41	1.08
Butternut	.567	2534	2.12	1.49	1.14
Pine, New Jersey	.478	2137	1.79	1.26	.967
Pine, pitch	.426	1904	1.59	1.12	.862
Pine, white	.418	1868	1.56	1.10	.845
Poplar, Lombardy	.397	1774	1.48	1.05	.80
Chestnut	.552	2333	1.95	1.38	1.05
Poplar, yellow	.563	2516	2.11	1.48	1.14

Dry wood at 45% boiler and grate efficiency will evaporate $\frac{8500 \times .45}{970.4} = 3.94.$ lbs. of water from and at 212 deg. F. per lb. of wood.

25% moisture wood at 45% boiler and grate efficiency will evaporate $\frac{6000 \times .45}{970.4} = 2.78$ lbs. of water from and at 212 deg. F. per lb. of wood.

40% moisture wood at 45% boiler and grate efficiency will evaporate $\frac{4600 \times .45}{970.4} = 2.13$ lbs. of water from and at 212 deg. F. per lb. of wood.

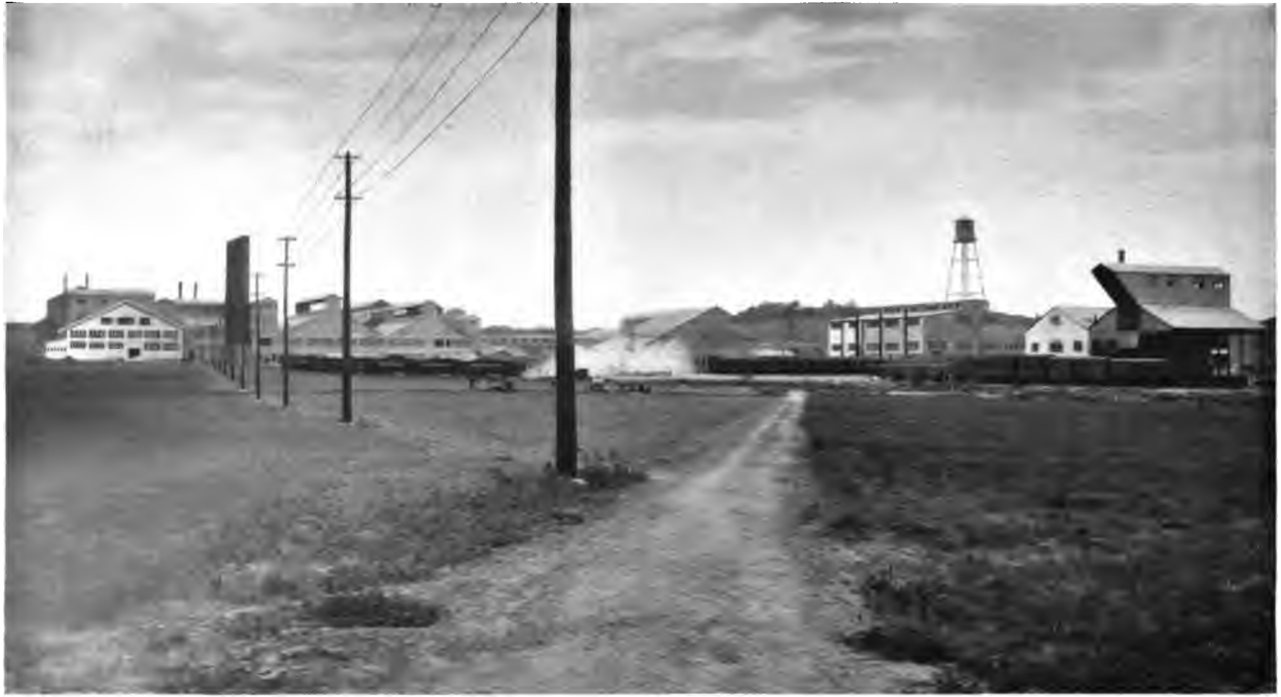
A general rule is that, when burned in boiler furnaces, 2¼ lbs. of dry wood are equal to one pound of an average quality of soft coal. Hence, if we assume a coal with an evaporative power of 8 lbs. of water from and at 212 deg. F. per lb. of coal, the dry wood will have a similar evaporative power equal to 3.55 lbs. of water from and at 212 degrees F., per 1 lb. of wood, or a boiler and grate efficiency of $\frac{3.55 \times 970.4}{8500} = 40.5\%$.

TABLE

COMPOSITION AND CALORIFIC VALUES OF VARIOUS DRY WOODS

(Gottlieb)

Kind of Wood	Carbon %	Hydrogen %	Nitrogen %	Oxygen %	Ash %	Calorific Value B.T.U. per lb.
Oak....	50.16	6.02	0.09	43.36	0.37	8,316
Ash....	49.18	6.27	0.07	43.91	0.57	8,480
Elm....	48.99	6.20	0.06	44.25	0.50	8,510
Beech..	49.06	6.11	0.09	44.17	0.57	8,591
Birch...	48.88	6.06	0.10	44.67	0.29	8,586
Fir.....	50.36	5.92	0.05	43.39	0.28	9,063
Pine....	50.31	6.20	0.04	43.08	0.37	9,153
Poplar..	49.37	6.21	0.96	41.60	1.86	7,834
Willow .	49.96	5.96	0.96	39.56	3.37	7,926
						8,495 Average



Plant of the Southwestern States Portland Cement Co., West Dallas, Tex.

BOILER TESTING

In a small publication of this kind, a detailed description of the methods to be followed in conducting an exhaustive boiler test would be out of place, but it is desirable on the part of operating engineers to know what efficiency they are obtaining with their equipment, and it is thought that a general outline of the data necessary to compute the efficiency of the boiler and grate would be of value.

Obtain the amount and temperature of the feed water entering the boiler for a period of eight or ten hours under average boiler room conditions. If extremely accurate results are desired, this water should be weighed, but for most purposes a water meter known to be fairly accurate or the gauge of a water tank may be used.

Record the steam pressure frequently during the same period. Readings should be taken every 20 minutes if the pressure varies considerably, but if it is fairly constant, every hour will be sufficient.

Record by tank gauge or otherwise the amount of oil used for the eight or ten hours, as the case may be, and reduce the result to pounds.

Compute the factor of evaporation for the average steam pressure and feed water temperature (see page 111) and determine the equivalent evaporation per hour from and at 212° F.; divide this result by the pounds of oil, consumed per hour, and if the result is in the neighborhood of 15 pounds of water per one pound of oil, the boiler and grate efficiency will be in the neighborhood of 75%, which is fairly good.

The quantity of steam used to vaporize the oil in percentage of the total evaporation of the boiler may be determined as described on page 120, and should not exceed 5%.

THE RELATION BETWEEN GRAVITY, HEAT UNITS PER POUND AND HEAT UNITS PER GALLON OF OIL FUEL

The amount of heat contained in the fuel, whether it be coal, oil or gas, is of vital interest to the consumer. In fact, many firms purchase their coal on a B.T.U. basis.

The consumer of oil fuel pays for his fuel at so much per barrel, and should be interested in the amount of heat contained in that barrel.

The heat value of oil is commonly given in B.T.U.'s per pound, thus:

Oklahoma crude of 35.4° B. gravity contains about 19,700 B.T.U.'s per pound, or 138,900 B.T.U.'s per gallon.

Oklahoma crude residuum of 24° B. gravity contains about 19,100 B.T.U.'s per pound, but has about 145,000 B.T.U.'s in a gallon, representing a gain of approximately 6100 heat units per gallon in favor of the residuum.

Crude	Gravity, Beaume	B.T.U. per lb.	B.T.U. per gal.	Compiled from
1. Ohio Lima	37.	19,900	139,181	U.S.Rep'ts
2. Texas, Beaumont .	22.	19,474	149,580	" "
3. Texas, Sour Lake..	20.	18,952	147,466	" "
4. La. Jennings......	24.	19,329	146,610	" "
5. Cal. Bakersfield...	16.	19,001	151,894	" "
6. Russian Baku.....	29.	19,967	146,638	" "
7. Okla. Residuum...	28.	19,266	142,376	T.T.Co.L'b
8. Okla. Residuum...	24.	19,117	145,002	" "
9. Texas Residuum ..	18.	18,417	145,218	" "
10. Texas Gas Oil	27.9	19,480	144,035	" "
11. Okla. Crude (G.P.)	32.2	19,450	140,001	" "
12. Okla. Crude	36.2	19,795	139,020	Am. Chem
13. Okla. Crude	35.4	19,685	138,897	" Jul
14. Pennsylvania	43.7	20,057	134,923	" "
15. Pennsylvania	38.2	19,782	137,366	" "
16. W. Virginia.......	40.	19,766	135,852	" "

SAME TESTS IN THE ORDER OF THEIR HEAT VALUE PER GALLON

Crude	Gravity, Beaume	B.T.U. per gal.
5. Calif. Bakersfield	16	151,894
2. Texas, Beaumont	22	149,580
3. Texas, Sour Lake	20	147,466
6. Russian, Baku	29	146,638
4. La. Jennings	24	146,610
9. Texas, Residuum	18	145,218
8. Okla. Residuum	24	145,002
10. Texas, Gas Oil	27.9	144,035
7. Okla. Residuum	28	142,376
11. Okla. Crude (G.P.)	32.2	140,001
1. Ohio, Lima	37	139,181
12. Okla. Crude	36.2	139,020
13. Okla. Crude	35.4	138,897
15. Pennsylvania	38.2	137,366
16. W. Virginia	40	135,852
14. Pennsylvania	43.7	134,923

METHOD OF OBTAINING FURNACE TEMPERATURE

An approximate method of obtaining the temperature of the furnace.

Apparatus.

A piece of ordinary fire-clay brick weighing about two pounds and the sharp edges of which have been rounded to prevent small pieces being broken off in handling.

A metal pail of about 12 to 14 quarts capacity.

A long handled, narrow shovel made with a piece of ½″ pipe and a sheet of about ⅛″ iron.

Weigh the pail empty and also when about two-thirds full of clear water, and record the temperature of the water.

Weigh the brick when dry.

Place brick in furnace where the temperature is desired and allow it to come to the temperature of the furnace.

Remove brick by means of the long handled shovel and place it in the pail of water as quickly as possible to minimize the heat loss due to radiation, and note carefully the maximum temperature rise of the water. Then the heat absorbed by the water and pail is equal to the heat given up by the brick, neglecting radiation.

Formula:

$$T = \frac{W}{w.\ S.}(t'-t) + t'$$

W = Weight of water plus the water equivalent of the pail.
w = Weight of the fire-clay egg.
S = Specific heat of fire-clay egg. (This will be about .22).
t' = Final temperature of the water.
t = Initial temperature of the water.

NOTE: The water equivalent of the pail is its weight multiplied by the specific heat of the substance of which it is made. (For wrought iron the value is about .11).

HEAT LOSSES IN FURNACE

A comparison of the heat losses in the furnace when burning coal and oil:

Coal—Alabama No. 1.

Ultimate Analysis of Dry Coal

	Per cent.
Carbon (C)	72.65
Hydrogen (H)	4.71
Oxygen (O)	6.49
Nitrogen (N)	1.42
Sulphur (S)	.96
Ash	13.77
	100.00

Oil Fuel.

Gravity	26° B.
Flash	265° F.
Fire	315° F.
Carbon (C)	86.75%
Hydrogen (H)	12.87%
Sulphur (S)	.38%
Oxygen (O)	Trace

Heating value per pound of dry coal, . .13,102 B.T.U.
" " " " " oil ....19,191 B.T.U.

Assuming complete combustion of carbon, hydrogen and sulphur, and knowing that

1 pound carbon requires 11.52 lbs. air to burn from C to CO_2
1 " hydrogen " 34.56 lbs. " " " " H to H_2O
1 " sulphur " 4.32 lbs. " " " " S to SO_2

The weight of air required for complete combustion of these three elements in the two fuels under comparison is as follows:

	Coal	Oil
Carbon.		
Coal = 11.52 lbs. air x .7265 =	8.37 lbs. air	
Oil = 11.52 " " x .8675 =		9.99 lbs. air.
Hydrogen.		
Coal = 34.56 " " x .0471 =	1.627 " "	
Oil = 34.56 " " x .1287 =		4.447 " "
Sulphur.		
Coal = 4.32 " " x .0096 =	.04 " "	
Oil = 4.32 " " x .0038 =		.016 " "
Pounds air required per 1 lb. of each fuel....	10.037 " "	14.453 " "

Deducting the weight of the ash from the coal, we have 1.00—.1377 = .8623 lbs. to every pound of coal, which will form part of the weight of the chimney gases and the pound of oil will also be represented in the chimney gases. Then the total weight of gases resulting from the combustion of 1 lb. of each fuel will be:

Coal = 10.037 + .8623 = 10.9 lbs. (dry chimney gas)
Oil = 14.453 + 1.00 = 15.453 " " " "

Assuming—

(1) Flue gas temperature to be 500° F. in each case.
(2) Temperature of air intake as 70° F.
(3) Moisture in the coal when fired as 2 %.

The sensible and latent heat lost in the flue gases will then be, for the two fuels:

Coal = .24 (500 − 70) x 10.9 + (142 + 970 + 288 x .48) .02 = 1149 B.T.U.

Oil = .24 (500 − 70) x 15.453 = 1594.7 B.T.U.
The specific heat of the gases of combustion being .24
" " " " " superheated steam " .48
And the factor (142 + 970 + 288 x .48) .02 representing the heat absorbed by the 2 % of moisture in the coal in raising it from 70° F. to 500° F.

As each pound of hydrogen burned forms 9 lbs. of water, there will also be an absorption of heat in raising this water to 500° F., as follows:

The hydrogen in the coal will form .0471 x 9 = .4239 lbs. water
The hydrogen in the oil will form .1287 x 9 = 1.1583 lbs. water

The loss being—

Coal, .4239 (142 + 970 + 288 x .48) = 529.9 B.T.U.
Oil, 1.1583 (72 + 970 + 288 x .48) = 1367 B.T.U.

Assuming that the oil is preheated to 140° F. before entering the furnace.

Explanation of Terms:

142 = 212° F.—70° F. and is the heat required to raise 1 lb. water from 70° F. to 212° F.

970 = Heat of vaporization of steam at 212° F. and is the heat required to change the water into steam at 212° F.

288 = 500° F.—212° F. and when multiplied by .48, is the heat required to superheat 1 lb. of steam to 500° F.

.48 = Specific heat of superheated steam at atmospheric pressure.

72 = Heat required to raise the temperature of 1 lb. of the water in the oil from 140° F. to 212° F.

The loss of heat due to the ash in the coal will be 13.77% of its total heating value, or 13,102 x .1377 = 1804 B.T.U.

An additional loss of heat when using oil will be in super-heating the steam used for atomizing from 212° F. to 500° F. as follows:

Assuming ½ pound of steam per pound of oil atomized—

$$\frac{(500-212) \times .48}{2} = 69.1 \text{ B.T.U. per lb. of oil.}$$

The total losses in the furnace for each fuel will be the sum of these separate losses, as follows:

	Coal	Oil
Gases	1149	1594.7
Combustion of hydrogen	529.9	1367.0
Ash of Coal	1804.0	
Steam for atomizing oil	.....	69.1
Total furnace losses, per lb. of fuel B.T.U. =	3482.9	3030.8

By subtracting these heat losses from the calorific value of the fuel and neglecting radiation, we obtain the heat available in the furnace for heating the water in the boiler, as follows:

Coal = 13,102—3483 = 9619 B.T.U.
Oil = 19,191—3031 = 16160 B.T.U.

Pueblo (Colo.) Station. The Texas Company

Pueblo (Colo.) Office. The Texas Company

In actual practice, the excess air supply when using coal will be considerably greater than when using oil, which will increase the furnace losses for coal due to the heat used to heat this air from 70° F. to 500° F. and the available heat for steam making will be correspondingly less. Deducting 3% from the heating value of each fuel to cover the losses due to furnace radiation (this will be about right for well-designed boiler settings), we have:

Coal = 9,619 − (13,102 x 3%) = 9,226 B.T.U.
Oil = 16,160 − (19,191 x 3%) = 15,584 B.T.U.

As an illustration of the close regulation of air supply with oil as compared to coal, these figures are very instructive: With 15,584 B.T.U. available for steam making we should obtain, with oil, $\frac{15,584}{970.4} = 16.06$ lbs. equivalent evaporation per lb. of oil, and the fact that 16 lbs. is sometimes obtained, indicates that the air supply is very close to that theoretically required, which accounts in a great measure for the high boiler and furnace efficiency obtainable with oil fuel.

With 9,226 B.T.U. available for steam making we should obtain with coal, $\frac{9,226}{970.4} = 9.5$ lbs. equivalent evaporation per lb. of coal, while in actual operation test of this coal would probably give results in the neighborhood of 7½ lbs. to 8 lbs., the difference being largely due to the excess air supply.

A flue gas temperature drop of 200° F. was observed, during a recent boiler test, when the fire was being replenished with coal.

APPROXIMATE RULE FOR DETERMINING B.T.U. PER POUND OF OIL

B.T.U. per pound = 18650 + 40 (Beaume reading − 10)

An article by H. C. Sherman and A. H. Kropff, in the October, 1908, issue of The Journal of the American Chemical Society, shows a table covering a wide range of refined and crude oils and illustrating the accuracy of the above formula.

The B.T.U. per pound are the results as determined by combustion in an ATWATER-MAHLER bomb calorimeter in the laboratories of Columbia University. The B.T.U. calculated were obtained by the above formula, and the percentage error column is the variation of the calculated from the determined results.

The variation seems to be greatest with California crudes, but of the 64 samples tested, in only one-ninth of the cases is the difference greater than one per cent, and in only one-thirtieth is it greater than two per cent. Hence it may safely be stated that B.T.U. determinations may be made for oils by means of the above formula with as great accuracy as by means of the chemical analysis.

HORSE POWER

Engine Horse Power:

An engine horse power is taken as 33,000 foot pounds of work in one minute, or 550 foot pounds of work in one second, and is expressed by the following formula:

$$\frac{P.L.A.N.}{33{,}000} = \text{The indicated horse power.}$$

Where

P is the mean effective pressure (as shown by a steam engine indicator) per square inch, acting on the piston.

L is the length of the stroke in feet.

A is the area of the piston in sq. inches (area of the piston rod to be deducted for the crank end).

N is the number of working strokes per minute (in double-acting steam engines it will be twice the number of revolutions).

Indicated Horse Power of Gas Engines.

The same formula is used for this calculation, except that the symbol N represents the total number of explosions per minute in all cylinders.

In computations for four cycle single cylinder, single-acting gas engines firing every fourth stroke, this will be the revolutions per minute, divided by two. For two cycle single cylinder, single-acting engines, firing every second stroke, or once every revolution, the value of N will be represented by the number of revolutions per minute.

Electrical Horse Power:

Multiply the volts by the amperes and the product will be watts. Since 746 watts is equivalent to an electrical horse power, dividing this product by 746 gives electrical horse power. If the circuit is an alternating one, multiply the product of volts and amperes by the power factor before dividing by 746.

Boiler Horse Power:

The evaporation of 34.5 pounds of water per hour from a feed water temperature of 212° F. into steam at the same temperature is a standard commercial boiler horse power and is considered as equivalent to the evaporation of 30 pounds of water per hour from a feed water temperature of 100° F. into steam at 70 pounds pressure. The former is called "The equivalent evaporation from and at 212° F.," and is obtained by multiplying the actual evaporation by the "factor of evaporation" for any given feed water temperature and boiler pressure.

Factor of Evaporation.

The factor of evaporation for any given feed water temperature and boiler pressure is calculated by dividing the total heat above 32° F. in one pound of steam at the given pressure minus the total heat in one pound of the feed water above 32° F. by the latent heat of steam at 212° F., which is 970.4 British Thermal Units. (See Marks and Davis, New Steam Tables.)

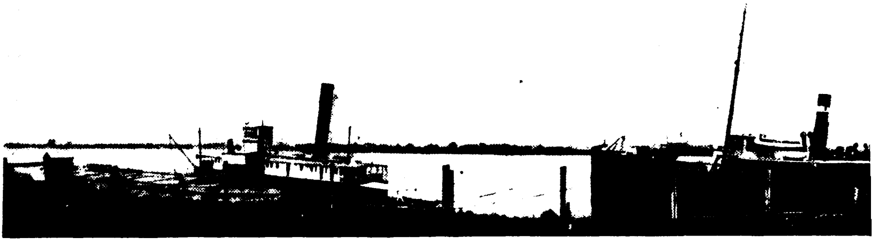
Example.

A boiler evaporates 5,000 pounds of water at 77° F. into steam at 91.3 lbs. gauge pressure every hour. What is the boiler horse power? Steam at 91.3 lbs. gauge pressure contains 1187.4 B.T.U. per pound (above 32° F.); water at 77° F. contains $77-32 = 45$ B.T.U. per pound (above 32° F.) $\frac{1187.4 - 45}{970.4} = 1.177$ factor of evaporation. 5,000 pounds of feed water per hour multiplied by $1.177 = 5{,}885$ lbs. of water which would have been evaporated into steam with the same heat used to evaporate 5,000 lbs. from 77 ° F. into steam at 91.3 lbs. if the feed water temperature had been 212° F. and the boiler pressure 0 lbs. gauge. 5,885 lbs. is the equivalent evaporation from and at 212° F. and divided by 34.5 lbs. gives 170.6 boiler horse power.

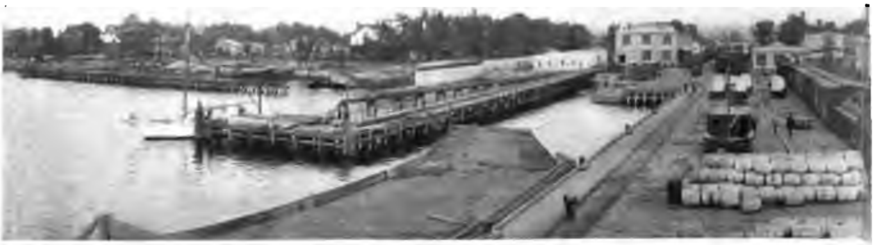
Similarly for any other feed water temperature and boiler pressure.

British Thermal Unit:

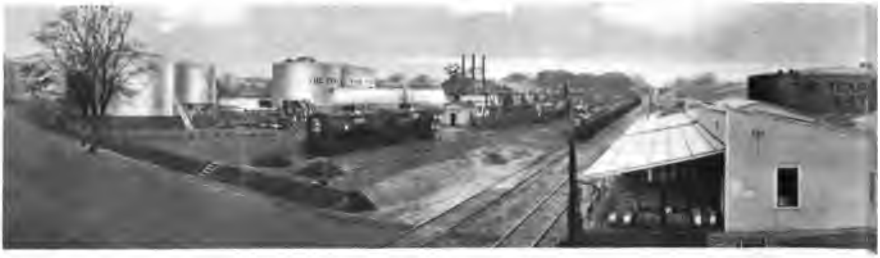
A British Thermal Unit (B.T.U.) is a standard unit for the measurement of heat, and is defined as the amount of heat imparted to one pound of pure water of a temperature of about 39° F. to raise its tem-



The Texas Company's Dock



The Texas Company's Docks and T



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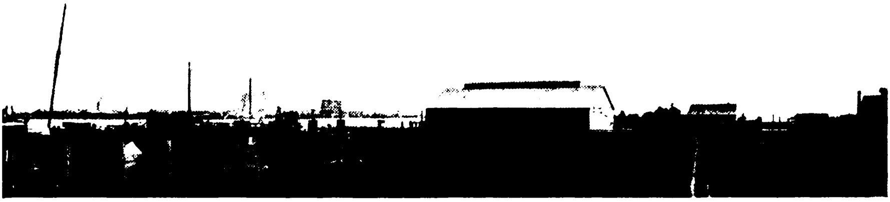


cks at Amesville, La., Terminal

Terminal at Bayonne, New York Harbor

erminal at Providence, R. I.

perature one degree Fahrenheit. Thus to raise the temperature of one pound of water from 39° F. to 40° F. requires one B.T.U. and to raise the temperature of one pound of boiler feed water from say 67° F. to 212° F. requires approximately 212 — 67 = 145 B.T.U.'s.

The Heat of Vaporization of Steam.

In raising the temperature of one pound of water from 67° F. to 212° F., 145 B.T.U.'s are required, but after a temperature of 212° F. is reached we can impart heat to the water until it is all changed into steam with no increase in temperature, 970.4 B.T.U.'s being required for this change of state in converting one pound of water at 212° F. into one pound of steam at atmospheric pressure. This value 970.4 B.T.U.'s, is known as the latent heat of steam or "The Heat of Vaporization of Steam" at 212° F.

Efficiency of the Boiler and Grate.

The efficiency of the boiler and grate is the amount of heat imparted to the water and steam per pound of fuel as fired, divided by the heat contained in one pound of the fuel. Thus, assume an equivalent evaporation from and at 212° F. of 7 pounds of water per one pound of coal containing 12,000 B.T.U.'s per pound.

7 times 970.4 = 6793 B.T.U.'s imparted to the water per one pound of coal, then we obtained in the boiler 6793 divided by 12,000, or 56.6% of the energy in the coal.

Similarly, suppose an equivalent evaporation of 15 pounds of water per one pound of oil containing 19,191 B.T.U. per pound.

$\frac{15 \times 970.4}{19,191} = \frac{14,556}{19,191} = 75.8\%$ of the energy in the oil is obtained in the boiler.

VALUE OF FLUE GAS ANALYSES

There are on the market today several types of apparatus suitable for determining correctly the component parts of the gases of combustion. The Orsatt apparatus is inexpensive, easily operated, and will enable the engineer to ascertain percentages by volume of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen (N) and oxygen (O) in the flue gas. There are also on the market, recording CO_2 gauges which show by means of a line drawn on a chart the per cent. of CO_2 in the flue gas for a period of 24 hours.

Such readings are of great value in showing the degree of excellence of combustion being obtained, as well as what changes should be made to increase the efficiency. A low determination of CO_2 and a high percentage of oxygen with no CO would indicate that an excess of air is entering the furnace, while a high CO determination indicates incomplete combustion and better regulation of air supply is necessary.

When burning oil fuel, 12% to 13% CO_2 should readily be obtained, and with careful firing by experienced men, the ideal condition of no excess air can be approached very closely, having at the same time no CO in the flue gases, indicating perfect combustion.

The following table indicates the value of a high percentage of CO_2 and its relation to the excess air co-efficient:

REQUIRED HOURLY EVAPORATION PER BOI
TEMPERATURES AN

Feed Water Temperature Deg. F	Steam Pr									
	0	10	20	30	40	50	60	70	80	9
50	29.51	29.29	29.14	29.02	28.92	28.84	28.77	28.70	28.64	28
60	29.77	29.55	29.40	29.28	29.18	29.09	29.02	28.95	28.89	28
70	30.04	29.81	29.66	29.54	29.44	29.35	29.27	29.21	29.15	29
80	30.31	30.08	29.93	29.80	29.70	29.61	29.53	29.46	29.40	29
90	30.59	30.36	30.20	30.07	29.97	29.88	29.80	29.73	29.67	29
100	30.88	30.64	30.47	30.34	30.24	30.15	30.07	30.00	29.93	29
110	31.17	30.93	30.76	30.63	30.52	30.43	30.34	30.27	30.20	30
120	31.46	31.22	31.05	39.91	30.80	30.71	30.63	30.55	30.48	30
130	31.76	31.52	31.34	31.20	31.09	30.99	30.91	30.83	30.76	30
140	32.07	31.82	31.64	31.50	31.38	31.29	31.20	31.12	31.05	30
150	32.39	32.12	31.94	31.80	31.68	31.58	31.50	31.42	31.35	31
160	32.71	32.44	32.26	32.11	31.99	31.89	31.80	31.72	31.65	31
170	33.03	32.76	32.58	32.43	32.31	32.20	32.11	32.03	31.96	31
180	33.37	33.09	32.90	32.75	32.63	32.52	32.43	32.34	32.27	32
190	33.71	33.43	33.23	33.08	32.95	32.84	32.75	32.66	32.59	32
200	34.06	33.77	33.57	33.41	33.28	33.17	33.08	32.99	32.91	32
212	34.49	34.18	33.98	32.80	33.69	33.58	33.48	33.39	33.31	33

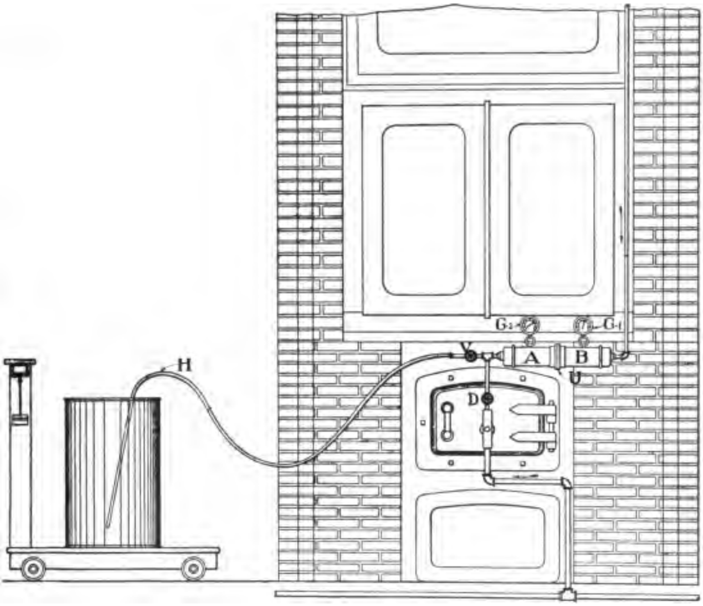
LER HORSE POWER AT VARIOUS FEED WATER D STEAM PRESSURES

essure in Pounds Gauge.

90	100	110	120	130	140	150	160	170	180	190	200
.59	28.54	28.49	28.45	28.41	28.37	28.33	28.29	28.26	28.23	28.20	28.17
.84	28.79	28.74	28.69	28.65	28.61	28.57	28.54	28.51	28.48	28.45	28.42
.09	29.04	28.99	28.94	28.90	28.86	28.82	28.78	28.75	28.72	28.69	28.66
.34	29.29	29.24	29.19	29.15	29.11	29.07	29.03	29.00	28.97	28.94	28.91
.61	29.55	29.50	29.45	29.41	29.37	29.33	29.29	29.25	29.22	29.19	29.16
.87	29.82	29.77	29.72	29.67	29.63	29.59	29.55	29.51	29.48	29.45	29.42
.14	30.09	30.04	29.99	29.94	29.90	29.86	29.82	29.78	29.74	29.71	29.68
.42	30.36	30.31	30.26	30.21	30.17	30.13	30.09	30.05	30.01	29.98	29.95
.70	30.65	30.59	30.54	30.49	30.45	30.41	30.37	30.33	30.29	30.25	30.22
.99	30.93	30.88	30.83	30.78	30.73	30.69	30.65	30.61	30.57	30.53	30.50
.28	31.22	31.17	31.12	31.07	31.02	30.97	30.93	30.89	30.85	30.81	30.78
.58	31.52	31.46	31.41	31.36	31.31	31.27	31.23	31.19	31.15	31.11	31.08
.89	31.83	31.77	31.71	31.66	31.61	31.56	31.52	31.48	31.44	31.40	31.37
.20	32.14	32.08	32.02	31.97	31.92	31.87	31.83	31.79	31.75	31.71	31.67
.52	32.45	32.39	32.33	32.28	32.23	32.18	32.17	32.10	32.06	32.02	31.98
.84	32.77	32.71	32.65	32.60	32.55	32.50	32.45	32.41	32.37	32.33	32.29
.24	33.17	33.11	33.05	33.99	32.94	32.89	32.84	32.80	32.76	32.72	32.68

VALUE OF FLUE GAS ANALYSIS

Per cent. CO_2 by volume as shown by analysis dry chimney gases	LIGHT OIL C. 84%; H. 13%; S. 0.8%; N. 0.2%; O. 1%; H_2O. 1%.		MEDIUM OIL C. 85%; H. 12%; S. 0.8%; N. 0.2%; O. 1%; H_2O 0.1%.		HEAVY OIL C. 86%; H. 11%; S. 0.8%; N. 0.2%; O. 1%; H_2O. 1%.	
	Lbs. of air per lb. of oil.	Ratio air supply to chemical requirements	Lbs. of air per lb. of oil	Ratio air supply to chemical requirements	Lbs. of air per lb. of oil	Ratio air supply to chemical requirements
4	51.40	3.607	51.93	3.704	52.45	3.803
5	41.31	2.899	41.71	2.975	42.12	3.054
6	34.58	2.427	34.90	2.490	35.23	2.554
7	29.77	2.089	30.04	2.143	30.31	2.198
8	26.17	1.836	26.39	1.883	26.62	1.930
9	23.37	1.640	23.56	1.680	23.75	1.722
10	21.12	1.482	21.29	1.518	21.45	1.555
11	19.83	1.391	19.43	1.386	19.58	1.419
12	17.76	1.246	17.88	1.276	18.01	1.306
13	16.46	1.155	16.57	1.182	16.69	1.210
14	15.36	1.078	15.45	1.102	15.55	1.127
15	14.39	1.010	14.48	1.033	14.57	1.056



Simply constructed apparatus for determining amount of steam consumed by oil burners

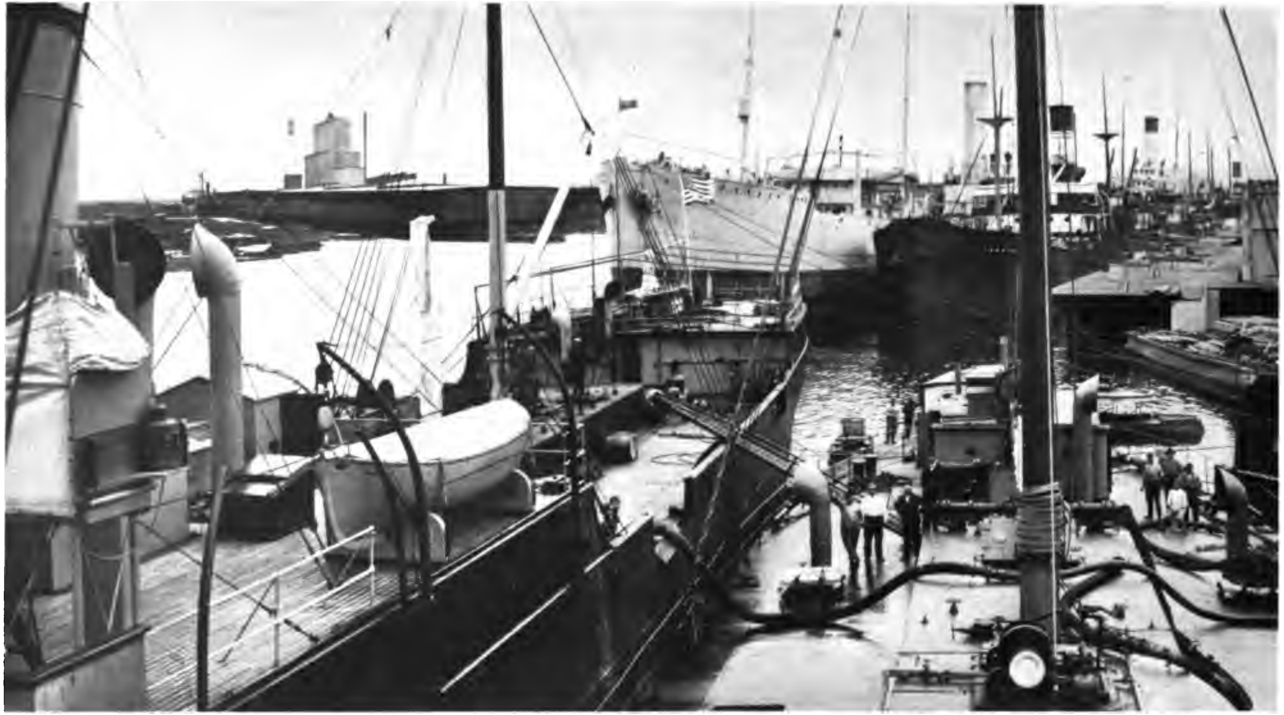
TO DETERMINE THE AMOUNT OF STEAM USED THROUGH THE BURNER TO VAPORIZE THE OIL

When a scientific test is being run on boilers using oil fuel, the amount of steam for atomization should be determined by an auxiliary boiler which supplies steam to the oil burners and to no other apparatus; but for ordinary purposes and as a means of obtaining a fair approximation to this result, the apparatus shown on page 119 will be sufficiently accurate.

SIMPLY CONSTRUCTED APPARATUS FOR DETERMINING AMOUNT OF STEAM CONSUMED BY OIL BURNERS

Required: Two 2 x 10-inch nipples (A and B); two 2 x ½-inch reducers; one 2-inch flange union (U); one blank flange, having a hole drilled in center, to fit between the flanges, size of hole about one-quarter inch, such as to create a difference in pressure of from 10 to 15 pounds. Place a good gasket on each side of blank flange. Two small 3″ gauges, (G1 and G2); two siphons for gauge connections, valves, fittings and short length of steam hose (H) to barrel.

Operation: During boiler test, record frequently pressures indicated by the two gauges. After test is completed, determine the average difference between the two pressures. Having valve D to burner closed, open valve V until difference indicated by gauges corresponds with that observed during boiler test. The moment this difference is obtained, immerse the end of the hose in a barrel partially filled with water



Fleet of The Texas Company's Tank Steamers at Port Arthur Terminal and previously weighed. Time the immersion accurately to a duration of three to five minutes and quickly jerk out the hose. The additional weight of the barrel of water will be the weight of steam consumed by the oil burner for a time equivalent to that of the immersion of the hose.

FEED WATER HEATERS

Saving made by heater:

Formula:

$$\% \text{ Saved} = \frac{H_2 - H_1}{H - H_1}$$

H = Total heat in one lb. of steam at the boiler pressure.
H1 = " " " feed water before entering heater.
H2 = " " " " " after leaving "

An approximate rule for ordinary practice is that a saving of 1 % is made by each increase of 11° F. in the temperature of the feed water, which is about .09% per degree.

Example:

Steam at 100 lbs. gauge pressure contains 1189 B.T.U. per pound.

Temperature of feed water entering the heater = 70° F. and contains 70 – 32 = 38 B.T.U. per pound.

Temperature of feed water leaving heater = 81° F. and contains 81 – 32 = 49 B.T.U. per pound.

Saving in raising temperature 11° F. =

$$\frac{H_2 - H_1}{H - H_1} = \frac{49 - 38}{1189 - 38} = .96\%$$

FUEL ECONOMIZERS

Economizers for boiler plants usually consist of vertical cast-iron tubes, made in sections and housed by brick-work. They are placed in the flue gas passage close to the boilers, the feed water entering the bank of tubes at one end while the hot gases of combustion enter at the other, traveling in a direction opposite to that of the water.

The following formula is used to determine the rise in temperature of the feed water:

$$\frac{A \cdot B \cdot C \cdot D \cdot}{E} = F$$

$$F - 15\% = G$$

$$\frac{G}{H} = J$$

A = Pounds of oil burned in the furnace per 24 hours.
B = Weight of gases of combustion. (Taken at 20 lbs. per 1 lb. of oil.)
C = Specific heat of flue gases = .24
D = Temperature entering gases — temperature gases leaving economizer = range.
E = Hours in operation.
F = B.T.U. per hour abstracted from gases to heat feed water.
F — 15% = allowance for radiation = G.
H = Pounds of feed water passing through economizer per hour.
J = Rise in temperature of feed water.

The steam pressure and feed water temperature before and after heating being known, the fuel saving can be computed by the following formula:

$$\text{Fuel saving in per cent.} = \frac{100\ (t - t_1)}{H + 32 - t_1}$$

t = temperature degrees F. of feed water after heating.
t_1 = temperature degrees F. of feed water before heating.
H = total B.T.U., above 32 deg. F., in one pound of steam at boiler pressure.

The more wasteful the boiler the greater the saving by using an economizer, hence in many coal burning installations a material saving can be effected in this way, but if the same plant was to use oil, the saving would be reduced, due to the much higher boiler and furnace efficiency obtained with the oil fuel.

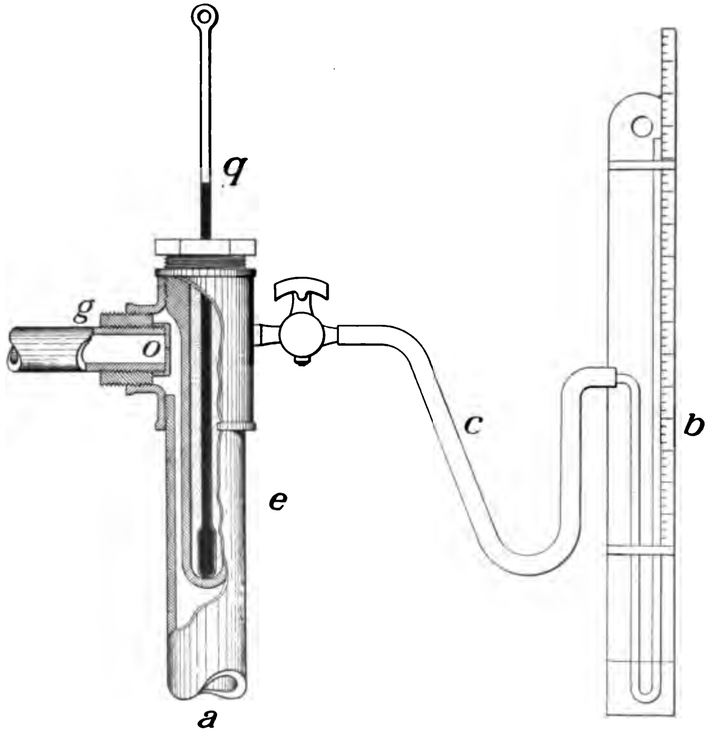
CALORIMETERS

An instrument for determining the percentage of moisture in steam is termed a calorimeter, two well-known types being the throttling and separating calorimeters. The former receives steam at boiler pressure and allows it to expand to approximately atmospheric pressure, causing a condition of superheat. Neglecting radiation, the heat in the steam at boiler pressure will be represented in that at atmospheric pressure.

The separating calorimeter depends for its operation on changing the direction of the steam entering the calorimeter, causing the moisture, which is heavier than the steam, to be thrown out, due to inertia. The moisture thus separated is measured, as is also the remaining steam, which is condensed for this purpose, and the relation between the two is the indication desired.

The throttling calorimeter is accurate only when the percentage of moisture does not exceed about 3%. A simple construction of this instrument can easily and quickly be made in the pipe shop, as shown in the following sketch.

The illustration explains itself. The ½″ nipple "g" is the sampling pipe; it should be short and should screw well into the pipe containing live steam, the moisture in which is to be measured. The best results are obtained when that part of the sampling pipe projecting into the main steam line is well perforated by ⅛″ holes, the end being plugged. There should be a globe valve between the main steam line and the calorimeter.



Throttling calorimeter of pipe-fittings

The cap over the end of the sampling tube contains a ⅛″ drilled hole, "o," as shown; on one side of this hole the steam will be at boiler pressure and on the calorimeter side its pressure will be very nearly atmospheric, as shown in inches of water by the water gauge "b." The thermometer "q" should read to about 400° F. for ordinary cases, and should rest on a small piece of waste at the bottom of the thermometer well; this well should be filled with cylinder oil. The nipple "e" should be about 1½″ x 10,″ and open at the bottom, as shown.

Allow the instrument to warm up thoroughly before taking readings, opening valve on sampling line slowly for this purpose.

Formula:

$xr + q$ = The heat in one pound of high pressure steam before reaching the calorimeter.

$Yc + .48\,(T1 - Tc)$ = Heat in one pound of steam in calorimeter after expanding, and is that due to the slight pressure plus that due to the superheat, caused by expanding from a higher pressure to a lower.

Neglecting radiation, these two are equal—

Hence:

$$xr + q = Yc + .48\,(T1 - Tc)$$

$$\text{Or, } x = \text{quality} = \frac{Yc - q + .48\,(T1 - Tc)}{r}$$

Symbols:

x = Quality of steam in main steam pipe.

r = Latent heat of the steam at boiler pressure.

q = Heat of the liquid due to the absolute pressure in main steam pipe.

Yc = Total heat in one pound of dry steam at the pressure in the calorimeter (may be taken as 1150.4 B.T.U., which corresponds to atmospheric pressure).

.48 is taken as the specific heat of superheated steam.

T1 = The reading of the thermometer in the calorimeter.

Tc = Normal temperature of the steam in the calorimeter due to the pressure indicated on the water gauge.

r, q and Yc may be found by consulting any reliable steam tables.

THE HYDROMETER AND BEAUME GRAVITY

An hydrometer is an instrument for determining the density of liquids. It usually consists of three parts: (a) A graduated stem or tube of uniform diameter; (b) a bulb containing air and also a thermometer; (c) a small bulb at the bottom containing shot which causes the instrument to float in the liquid in an upright position.

The scale may be graduated to read the specific gravity, but when used to determine the density of oils, it usually reads in Beaume degrees.

The graduations on the Beaume hydrometer are the figures of an arbitrary scale, the instrument being made in two forms, one for the density of liquids heavier than water and one for those lighter than water. With the former type, the zero reading corresponds to the specific gravity of pure water, which is 1.00, but the scale on the Beaume hydrometer for liquids lighter than water is so graduated that the reading 10 corresponds to the specific gravity of pure water.

The standard of measurement for the density of oils is the reading of the Beaume hydrometer for liquids lighter than water when the temperature of the oil is 60° F. A rough rule for the correction at any other temperature is: For every 10° F. above 60° F. subtract one degree from the Beaume reading, and for every 10° F. below 60° add one degree, thus:

The hydrometer indicates a gravity of a certain oil fuel to be "27.5° B." and the temperature of the the oil for this reading is 75° F. The temperature then is 15° F. above 60° F., and the correct gravity is $27.5 - \frac{15}{10} = 26°$ B.

Or:—

The hydrometer indicates a gravity of 24° B. at a temperature of 40° F. Then the correct gravity will be

$$24 + \frac{60-40}{10} = 26° \text{ B.}$$

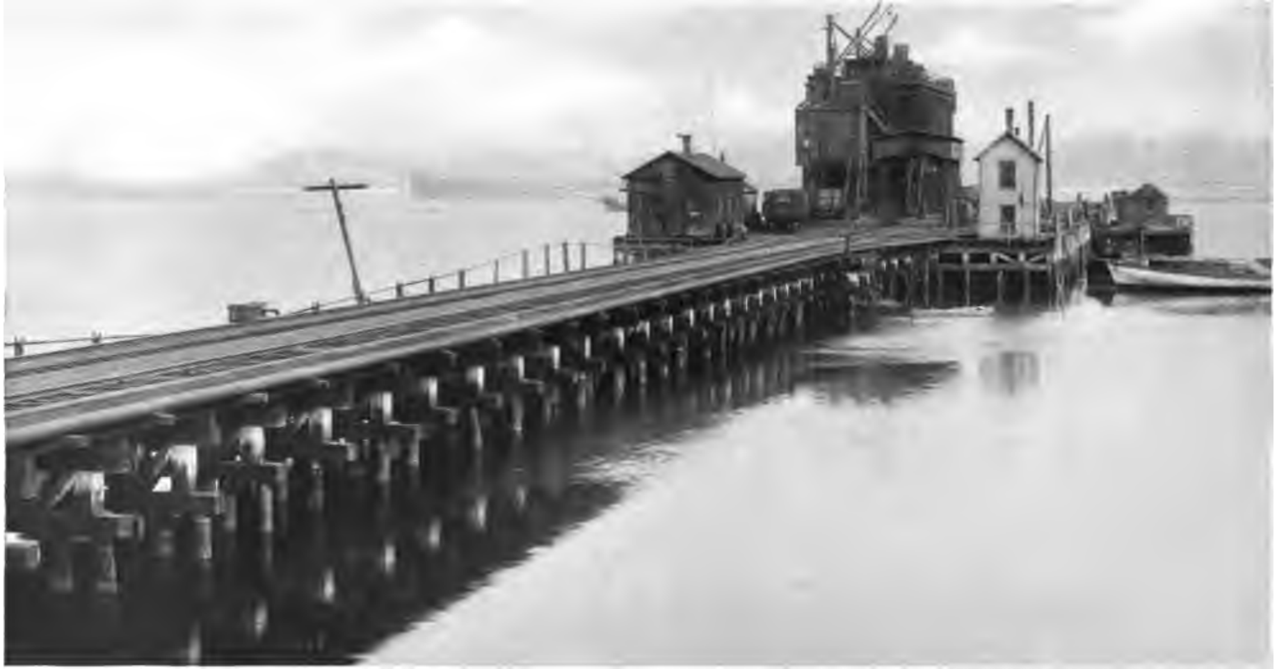
Formula for reducing Beaume reading (liquids lighter than water) to specific gravity:

$$\text{Specific Gravity} = \frac{140}{130 + \text{degrees Beaume}}$$

Thus:

Gravity Beaume = 26 at 60° F.

$$\text{Specific Gravity} = \frac{140}{130 + 26} = .897$$ (See table, page 131).



Terminal of The Texas Company at Providence, R. I.

QUANTITY OF AIR REQUIRED FOR PERFECT COMBUSTION OF FUELS

(Calorific Value of Fuels, Poole)

FUEL	COMPOSITION				Air per lb. Cubic Ft. *
	Carbon	Hyd'gen	Oxygen	Nit'gen	
Coke	98.0	0.5	....	....	162.06
Coal, Anthracite	95.4	2.2	1.8	0.5	144.60
" Bituminous	87.0	5.0	4.0	....	143.40
" Coking	85.0	5.0	6.0	....	139.41
" Cannel	84.0	6.0	8.0	....	141.07
" Smithy	77.0	5.0	15.0	....	123.15
Charcoal	90.0	2.0	....	....	133.90
Lignite	71.0	5.0	19.0	....	112.43
Peat, Dry	58.0	6.0	30.0	....	92.36
Wood, Dry	50.0	6.0	42.0	1.0	73.36
Petroleum	85.0	14.0	1.0	....	172.86
Natural Gas	68.7	22.5	1.0	6.2	227.93
Coal Gas	58.0	23.7	1.4	3.8	233.06
Water Gas	34.0	5.9	43.0	3.4	50.70
Producer Gas	1.0	5.0	21.0	69.0	11.56

*These values are theoretical and in practice an excess is always required.

RELATION OF THE COMPONENT PARTS OF AIR BY WEIGHT AND VOLUME

By Volume	
Nitrogen	78.35
Oxygen	20.77
Aqueous Vapor	.84
Carbonic Acid	.04
	100.00

By Weight (Deducting Carbonic Acid and Aqueous Vapor)	
Nitrogen	76.83
Oxygen	23.17
	100.00

TABLE

OF BEAUME GRAVITY, CORRESPONDING SPECIFIC GRAVITY AND WEIGHT PER GALLON FOR LIQUIDS LIGHTER THAN WATER

Beaume	Specific Gravity	Pounds in Gallon	Beaume	Specific Gravity	Pounds in Gallon
10	1.0000	8.331	51	0.7750	6.457
11	0.9930	8.273	52	0.7710	6.423
12	0.9860	8.214	53	0.7670	6.390
13	0.9790	8.156	54	0.7630	6.357
14	0.9720	8.098	55	0.7585	6.319
15	0.9655	8.044	56	0.7545	6.286
16	0.9595	7.994	57	0.7505	6.252
17	0.9530	7.939	58	0.7470	6.223
18	0.9465	7.885	59	0.7430	6.190
19	0.9400	7.831	60	0.7390	6.157
20	0.9340	7.781	61	0.7355	6.127
21	0.9280	7.731	62	0.7315	6.094
22	0.9220	7.681	63	0.7280	6.065
23	0.9165	7.635	64	0.7240	6.032
24	0.9105	7.585	65	0.7205	6.002
25	0.9045	7.536	66	0.7165	5.969
26	0.8990	7.490	67	0.7130	5.940
27	0.8930	7.440	68	0.7095	5.911
28	0.8870	7.390	69	0.7060	5.882
29	0.8815	7.344	70	0.7025	5.853
30	0.8755	7.294	71	0.6990	5.823
31	0.8700	7.248	72	0.6955	5.794
32	0.8650	7.206	73	0.6920	5.765
33	0.8595	7.160	74	0.6890	5.740
34	0.8545	7.119	75	0.6855	5.711
35	0.8490	7.073	76	0.6820	5.682
36	0.8440	7.031	77	0.6790	5.657
37	0.8395	6.994	78	0.6755	5.628
38	0.8345	6.952	79	0.6720	5.598
39	0.8295	6.911	80	0.6690	5.573
40	0.8250	6.873	81	0.6655	5.544
41	0.8205	6.836	82	0.6620	5.515
42	0.8155	6.794	83	0.6585	5.486
43	0.8110	6.756	84	0.6545	5.453
44	0.8065	6.719	85	0.6510	5.423
45	0.8015	6.677	86	0.6480	5.398
46	0.7970	6.640	87	0.6450	5.373
47	0.7925	6.602	88	0.6420	5.349
48	0.7885	6.569	89	0.6390	5.324
49	0.7840	6.532	90	0.6365	5.303
50	0.7795	6.494			

To obtain the weight of oil fuel per barrel, multiply the pounds in one gallon by 42.

CAPACITY OF CYLINDRICAL TANKS IN U. S. GALLONS FOR EACH FOOT OF LENGTH

Diameter of Tank	Number of U. S. Gallons	Cubic Feet & Area in Sq. Feet
1 Ft.	5.87	.785
1 " 6 in.	13.22	1.767
2 " 0 "	23.50	3.142
2 " 6 "	36.72	4.909
3 " 0 "	52.88	7.069
3 " 6 "	71.97	9.621
4 " 0 "	94.00	12.566
4 " 6 "	118.97	15.90
5 " 0 "	146.88	19.63
5 " 6 "	177.72	23.76
6 " 0 "	211.51	28.27
6 " 6 "	248.23	33.18
7 " 0 "	287.88	38.48
7 " 6 "	330.48	44.18
8 " 0 "	376.01	50.27
8 " 6 "	424.48	56.75
9 " 0 "	475.89	63.62
9 " 6 "	530.24	70.88
10 " 0 "	587.52	78.54
10 " 6 "	647.74	86.59
11 " 0 "	710.90	95.03
11 " 6 "	776.99	103.87
12 " 0 "	846.03	113.10
12 Ft. 6 in.	918.00	122.72
13 " 0 "	992.91	132.73
13 " 6 "	1070.80	143.14
14 " 0 "	1151.50	153.94
14 " 6 "	1235.30	165.13
15 " 0 "	1321.90	176.71
15 " 6 "	1411.50	188.69
16 " 0 "	1504.10	201.06
16 " 6 "	1599.50	213.82
17 " 0 "	1697.90	226.98
17 " 6 "	1799.30	240.53
18 " 0 "	1903.60	254.47
18 " 6 "	2010.80	268.80
19 " 0 "	2120.90	283.53
19 " 6 "	2234.00	298.65
20 " 0 "	2350.1	314.16
20 " 6 "	2469.1	330.06
21 " 0 "	2591.00	346.36
21 " 6 "	2715.80	363.05
22 " 0 "	2843.60	380.13
22 " 6 "	2974.30	397.61
23 " 0 "	3108.00	415.48
23 " 6 "	3244.60	433.74
24 " 0 "	3384.10	452.39

42 gallons equal one barrel oil fuel.

5.614 cubic feet in one 42 gallon barrel.

To find the capacity of tanks greater than the largest size given in the table, look in the table for a tank of ½ of the given diameter and multiply its capacity by four, or one of one-third its diameter and multiply its capacity by nine, etc.

TAP DRILLS

Diameter of Tap	No. of Threads to Inch	Size of Drill for V Thread
1/4	16 — 18 — 20	5/32 — 11/64 — 15
9/32	16 — 18 — 20	3/16 — 13/64 — 3
5/16	16 — 18	7/32 — 15/64..
11/32	16 — 18	1/4 — 17/64
3/8	14 — 16 — 18	17/64 — 9/32 — M
13/32	14 — 16 — 18	N — 5/16 — P
7/16	14 — 16	Q — 11/32
15/32	14 — 16	23/64 — 3/8
1/2	12 — 13 — 14	3/8 — W — 25/64
17/32	12 — 13 — 14	13/32 — 27/64 — 7/16
9/16	12 — 14	7/16 — 29/64
19/32	12 — 14	31/64 — 1/2
5/8	10 — 11 — 12	31/64 — 1/2 — 33/64
21/32	10 — 11 — 12	33/64 — 17/32 — 35/64
11/16	11 — 12	9/16 — 37/64
23/32	11 — 12	19/32 — 39/64
3/4	10 — 11 — 12	39/64 — 5/8 — 41/64
25/32	10 — 11 — 12	41/64 — 21/32 — 43/64
13/16	10	43/64
27/32	10	45/64
7/8	9 — 10	23/32 — 47/64
29/32	9 — 10	3/4 — 49/64
15/16	9 —	25/32
31/32	9	13/16
1	8	53/64
1 1/32	8	55/64
1 1/16	8	57/64
1 3/32	8	59/64
1 1/8	7 — 8	59/64 — 61/64
1 5/32	7 — 8	61/64 — 63/64
1 3/16	7 — 8	63/64 — 1 1/64
1 7/32	7 — 8	1 1/64 — 1 3/64
1 1/4	7	1 3/64
1 9/32	7	1 5/64
1 5/16	7	1 7/64
1 11/32	7	1 9/64
1 3/8	6	1 1/8
1 13/32	6	1 5/32
1 7/16	6	1 3/16

TAP DRILLS (Continued)

Diameter of Tap	No. of Threads to Inch	Size of Drill for V Thread
1 15/32	6	1 7/32
1 1/2	6	1 17/64
1 17/32	6	1 19/64
1 9/16	6	1 21/64
1 19/32	6	1 23/64
1 5/8	5 — 5 1/2	1 21/64 — 1 23/64
1 21/32	5 — 5 1/2	1 23/64 — 1 25/64
1 11/16	5 — 5 1/2	1 25/64 — 1 27/64
1 23/32	5 — 5 1/2	1 27/64 — 1 29/64
1 3/4	5	1 29/64
1 25/32	5	1 31/64
1 13/16	5	1 33/64
1 27/32	5	1 35/64
1 7/8	4 1/2 — 5	1 35/64 — 1 37/64
1 29/32	4 1/2 — 5	1 37/64 — 1 39/64
1 15/16	4 1/2 — 5	1 39/64 — 1 41/64
1 31/32	4 1/2 — 5	1 41/64 — 1 43/64
2	4 1/2	1 43/64

PIPE TAP DRILLS

Diam. of Tap or Size of Pipe	Diameter of Drill	Diam. of Tap or Size of Pipe	Diameter of Drill
1/8″	21/64	1 1/4	1 15/32
1/4″	29/64	1 1/2	1 23/32
3/8″	19/32	2	2 3/16
1/2″	23/32	2 1/2	2 11/16
3/4″	15/16	3	3 5/16
1	1 3/16	3 1/2	3 13/16

Norfolk (Va.) Terminal. The Texas Company

Galveston Station. The Texas Company

DIMENSIONS OF STANDARD WELDED PIPE

Size	DIAMETER		Thickness of Metal	No. of Thread per Inch	Weight of Pipe per Lineal Foot	CIRCUMFERENCE		Length of Pipe per Sq. Foot of		Length of Pipe containing one cubic Foot	U. S. Gallons contained in one Lineal Foot of Pipe	Water Contained in one LinealFoot of Pipe
	External	Internal				External	Internal	External Surface	Internal surface			
Inches	Inches	Inches	Inches		Pounds	Inches	Inches	Feet	Feet	Lineal Feet	Gallons	Pounds
⅛	.405	.269	.068	27	.246	1.272	.845	9.431	14.2	2533.8	.003	.0246
¼	.54	.364	.088	18	.426	1.696	1.144	7.074	10.494	1383.8	.0054	.0451
⅜	.675	.493	.091	18	.570	2.121	1.549	5.659	7.748	754.36	.0099	.0827
½	.84	.622	.109	14	.855	2.639	1.954	4.547	6.141	473.91	.0158	.1316
¾	1.05	.824	.113	14	1.140	3.299	2.589	3.638	4.636	270.03	.0277	.2309
1	1.315	1.049	.133	11½	1.690	4.131	3.296	2.905	3.641	166.62	.0449	.3742
1¼	1.66	1.38	.140	11½	2.290	5.215	4.335	2.301	2.768	96.275	.0777	.6477
1½	1.90	1.61	.145	11½	2.740	5.969	5.058	2.01	2.372	70.733	.1058	.8816
2	2.375	2.067	.154	11½	3.690	7.461	6.494	1.608	1.848	42.913	.1743	1.4530
2½	2.875	2.469	.203	8	5.850	9.032	7.757	1.329	1.547	30.077	.2487	2.0732
3	3.5	3.068	.216	8	7.660	10.996	9.638	1.091	1.245	19.479	.3840	3.2012
3½	4.0	3.548	.226	8	9.240	12.566	11.146	.955	1.077	14.565	.5136	4.2812
4	4.5	4.026	.237	8	10.900	14.137	12.648	.849	.949	11.312	.6613	5.5125
4½	5.0	4.506	.247	8	12.700	15.708	14.156	.764	.848	9.0301	.8284	6.9053
5	5.563	5.047	.258	8	14.90	17.477	15.856	.687	.757	7.1979	1.0393	8.6629
6	6.625	6.065	.280	8	19.20	20.813	19.054	.577	.630	4.9844	1.5008	12.5101
7	7.625	7.023	.301	8	23.80	23.955	22.063	.501	.544	3.7173	2.0124	16.7743
8	8.625	7.981	.322	8	28.90	27.096	25.073	.443	.479	2.8784	2.5988	21.6627
9	9.625	8.941	.342	8	34.30	30.238	28.089	.397	.427	2.2935	3.2616	27.1876
10	10.75	10.02	.365	8	41.20	33.772	31.479	.355	.381	1.8262	4.0963	34.1456
12	12.75	12.00	.375	8	50.90	40.055	37.699	.300	.318	1.2732	5.8752	48.9735

HIGH TEMPERATURES JUDGED BY COLOR

COLORS	Temperature (Degrees Fahrenheit)
Red, Visible in the Dark	752
" " " " Twilight	885
" " " " Daylight	975
" " " " Sunlight	1077
Dark Red	1292
Dull Cherry-red	1472
Cherry-red	1652
Bright Cherry-red	1832
Orange Red	2012
" Yellow	2192
Yellow White	2372
White Welding Heat	2552
Brilliant White	2732
Dazzling White (Bluish White)	2912

TEMPERING STEEL

Colors and Temperatures for Various Instruments

(Haswell)

Temperature	Color	Instruments
430	Very Faint Yellow	Hammer Faces, Drills, Lancets, Razors, etc.
450	Pale Straw Color	" " " "
470	Full Yellow	Shears, Scissors, Turning Tools, Penknives.
490	Brown Color	" " " "
510	Brown with Purple Spots	Plane Irons, Saws, Knives, etc.
538	Purple	" " " "
550	Dark Blue	Cold Chisels, Axes, Cutlery, etc.
560	Full Blue	" " " "
600	Grayish Blue, Verging on Black	For Spring Temper, as Saws, Sword Blades, etc.

AREAS OF CIRCLES

Diameter	0	⅛	¼	⅜	½	⅝	¾	⅞	Diameter
0	.0	.01227	.0490	.1104	.1963	.3068	.4417	.6013	.0
1	.7854	.9940	1.2272	1.484	1.767	2.073	2.405	2.761	1
2	3.1416	3.546	3.976	4.430	4.908	5.411	5.939	6.491	2
3	7.0686	7.669	8.295	8.946	9.621	10.32	11.04	11.79	3
4	12.56	13.36	14.18	15.03	15.90	16.80	17.72	18.66	4
5	19.63	20.62	21.64	22.69	23.75	24.85	25.96	27.10	5
6	28.27	29.46	30.68	31.91	33.18	34.47	35.78	37.12	6
7	38.48	39.87	41.28	42.71	44.17	45.66	47.17	48.70	7
8	50.26	51.84	53.45	55.08	56.74	58.42	60.13	61.86	8
9	63.61	65.39	67.20	69.02	70.88	72.76	74.66	76.58	9
10	78.54	80.51	82.51	84.54	86.59	88.66	90.76	92.88	10
11	95.03	97.20	99.40	101.6	103.8	106.1	108.4	110.7	11
12	113.1	115.4	117.8	120.2	122.7	125.1	127.6	130.1	12
13	132.7	135.3	137.8	140.5	143.1	145.8	148.4	151.2	13
14	153.9	156.7	159.4	162.3	165.1	167.9	170.8	173.7	14
15	176.7	179.6	182.6	185.6	188.6	191.7	194.8	197.9	15
16	201.0	204.2	207.3	210.6	213.8	217.0	220.3	223.6	16
17	226.9	230.3	233.7	237.1	240.5	243.9	247.4	250.9	17
18	254.4	258.0	261.5	265.1	268.8	272.4	276.1	279.8	18
19	283.5	287.2	291.0	294.8	298.6	302.4	306.3	310.2	19
20	314.1	318.1	322.0	326.0	330.0	334.1	338.1	342.2	20
21	346.3	350.5	354.6	358.8	363.0	367.2	371.5	375.8	21
22	380.1	384.4	388.8	393.2	397.6	402.0	406.4	410.9	22

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	367.2	371.5	375.8	21
22	380.1	384.4	388.8	393.2	397.6	402.0	406.4	410.9	22
23	415.4	420.0	424.5	429.1	433.7	438.3	443.0	447.6	23
24	452.3	457.1	461.8	466.6	471.4	476.2	481.1	485.9	24
25	490.8	495.7	500.7	505.7	510.7	515.7	520.7	525.8	25
26	530.9	536.0	541.1	546.3	551.5	556.7	562.0	567.2	26
27	572.5	577.8	583.2	588.5	593.9	599.3	604.8	610.2	27
28	615.7	621.2	626.8	632.3	637.9	643.5	649.1	654.8	28
29	660.5	666.2	671.9	677.7	683.4	689.3	695.1	700.9	29
30	706.8	712.7	718.6	724.6	730.6	736.6	742.6	748.6	30
31	754.8	760.9	776.9	773.1	779.3	785.5	791.7	797.9	31
32	804.2	810.5	816.9	823.2	829.6	836.0	842.4	848.8	32
33	855.3	861.8	868.3	874.8	881.4	888.0	894.6	901.3	33
34	907.9	914.6	921.3	928.1	934.8	941.6	948.4	955.3	34
35	962.1	969.0	975.9	982.8	989.8	996.8	1003.8	1010.8	35
36	1017.9	1025.0	1032.1	1039.2	1046.4	1053.5	1060.7	1068.0	36
37	1075.2	1082.5	1089.8	1097.1	1104.5	1111.8	1119.2	1126.7	37
38	1134.1	1141.6	1149.1	1156.6	1164.2	1171.7	1179.3	1186.9	38
39	1194.6	1202.3	1210.0	1217.7	1225.4	1233.2	1241.0	1248.8	39
40	1256.6	1264.5	1272.4	1280.3	1288.3	1296.2	1304.2	1312.2	40
41	1320.3	1328.3	1336.4	1344.5	1352.7	1360.8	1369.0	1377.2	41
42	1385.4	1393.7	1402.0	1410.3	1418.6	1427.0	1435.4	1443.8	42
43	1452.2	1460.7	1469.1	1477.6	1486.2	1494.7	1503.3	1511.9	43
44	1520.5	1529.2	1537.9	1546.6	1555.3	1564.0	1572.8	1581.6	44
45	1590.4	1599.3	1608.2	1617.0	1626.0	1634.9	1643.9	1652.9	45
46	1661.9	1671.0	1680.0	1689.1	1698.2	1707.4	1716.5	1725.7	46
47	1734.9	1744.2	1753.5	1762.7	1772.1	1781.4	1790.8	1800.1	47
48	1809.6	1819.0	1828.5	1837.9	1847.5	1857.0	1866.6	1876.1	48
49	1885.7	1895.4	1905.0	1914.7	1924.4	1934.2	1943.9	1953.7	49
50	1963.5	1973.3	1983.2	1993.1	2003.0	2012.9	2022.8	2032.8	50

HORSE POWER OF BELTS FOR GENERAL USE

"POWER"

Belt Speed in Feet Per Minute	Width of Belt Used.											
	2	3	4	5	6	8	10	12	14	16	18	20
	Horse power that can be transmitted.											
400	1	1½	2	2½	3	4	5	6	7	8	9	10
600	1½	2¼	3	3¾	4½	6	7½	9	10½	12	13½	15
800	2	3	4	5	6	8	10	12	14	16	18	20
1000	2½	3¾	5	6¼	7½	10	12½	15	17½	20	22½	25
1200	3	4½	6	7½	9	12	15	18	21	24	27	30
1500	3¾	5¾	7½	9½	11½	15	19	23	26½	30	33¾	38
1800	4½	6¾	9	11¼	13½	18	22½	27	31½	36	40½	45
2000	5	7½	10	12¼	15	20	24½	30	35	40	45	49
2400	6	9	12	15	18	24	30	36	42	48	54	60
2800	7	10½	14	17½	21	28	35	42	49	56	63	70
3000	7½	11¼	15	18¾	22½	30	37½	45	52½	60	67½	75
3500	8¾	13	17½	22	26	35	44	52	61	70	79	88
4000	10	15	20	25	30	40	50	60	70	80	90	100
4500	11¼	17	22½	28	34	45	56	64	78	90	102	112
5000	12½	19	25	31	38	50	62	76	87½	100	112	125

To find the belt speed, multiply pulley diameter by 3 1/7 or 3.1416, as you prefer. If diameter is in inches divide by 12 to get feet. Multiply this by the revolutions per minute to get Belt Speed.

DECIMAL EQUIVALENTS

1/64	.015625	23/64	.359375	11/16	.6875
1/32	.03125	3/8	.375	45/64	.703125
3/64	.046875	25/64	.390625	23/32	.71875
1/16	.0625	13/32	.40625	47/64	.734375
5/64	.078125	27/64	.421875	3/4	.75
3/32	.09375	7/16	.4375	49/64	.765625
7/64	.109375	29/64	.453125	25/32	.78125
1/8	.125	15/32	.46875	51/64	.796875
9/64	.140625	31/64	.484375	13/16	.8125
5/32	.15625	1/2	.5	53/64	.828125
11/64	.171875	33/64	.515625	27/32	.84375
3/16	.1875	17/32	.53125	55/64	.859375
13/64	.203125	35/64	.546875	7/8	.875
7/32	.21875	9/16	.5625	57/64	.890625
15/64	.234375	37/64	.578125	29/32	.90625
1/4	.25	19/32	.59375	59/64	.921875
17/64	.265625	39/64	.609375	15/16	.9375
9/32	.28125	5/8	.625	61/64	.953125
19/64	.296875	41/64	.640625	31/32	.96875
5/16	.3125	21/32	.65625	63/64	.984375
21/64	.328125	43/64	.671875	1.	1.
11/32	.34375				

EQUIVALENT VALUE OF ELECTRICAL AND MECHANICAL UNITS

One K.W. Hour —	1,000 watt hours. 1.34 H.P. hours. 2,654,200 foot pounds. 3,412 heat units. 3.53 lbs. water evaporated from and at 212° F.
One H.P. Hour —	.746 K.W. hour. 1,980,000 foot pounds. 2,545 heat units. 2.64 lbs. water evaporated from and at 212° F.

MISCELLANEOUS DATA

1 gal. of water weighs 8 1/3 lbs. (at 62° F.).

To obtain the weight of a gallon of oil, multiply the weight of a gallon of water by the specific gravity of the oil.

1 gal. of water contains 231 cu. inches (at 62° F.).

1 cu. ft. of water weighs 62.4 lbs. (at 39.1° F.).

1 cu. ft. of water contains 7.48 gallons.

When water is converted into steam, it expands to approximately 1700 times its original volume. Thus, one cu. inch of water will expand to approximately one cu. ft. of steam at atmospheric pressure.

Water in the presence of saturated steam has the same temperature as the steam.

Sea water freezes at 27° F. The ice is fresh.

1 pound pressure per sq. inch is equivalent to the weight of a column of water 2.31 ft. high, having a cross-sectional area of 1 sq. inch also to a similar column of mercury 2.03″ in height (the water being at a temperature of 62° F. and the mercury at 32° F.).

A column of water at 62° F. one foot high and having a cross-sectional area of 1 sq. inch is equivalent to a pressure of .433 pounds per sq. inch.

The pressure of the atmosphere at sea level is 14.7 lbs. per sq. inch, and is equivalent to a column of water 33.9 ft. high, or a column of mercury 30″ high (both at 62° F.).

A column of mercury at 62° F. one inch high and having a cross-sectional area of one sq. inch (1 cu. inch) is equivalent to a pressure of .491 lbs. per sq. inch.

26.79 cu. ft. of steam under an absolute pressure of 14.7 lbs. weigh 1 lb.

1 cu. ft. of steam under an absolute pressure of 14.7 lbs. weighs .037 lbs.

1 British Thermal Unit is equivalent to 778 foot pounds of energy.

Volts × amperes = watts.

746 watts = 1 electrical H.P.

1 – 16 C.P. incandescent lamp (110 v.) requires 55 watts (not Tungsten, etc).

Volts × amperes × power factor = effective watts (alternating circuits).

$$\text{Power factor} = \frac{\text{Indicating wattmeter reading}}{\text{Apparent watts}}$$

Apparent watts = volts × amperes = volt-amperes.

THE TEXAS COM
TEXACO
LIGHT
AXLE GREASE
UNIFORM QUALITY
PORT ARTHUR
THE TEXAS COM
TEXACO
No
CUP GREASE
UNIFORM QUALITY
PORT ARTHUR

TEXACO LUBRICATING OILS AND GREASES

Texaco lubricants are manufactured from a wide range of crudes and consist of oils and greases especially adapted to meet the exacting requirements of modern lubricating practice.

TEXACO CYLINDER OILS

Filtered Cylinder Oil
Unfiltered Cylinder Oil

All desirable grades, either mineral or compounded, to meet the widest range of steam and mechanical conditions.

TEXACO ENGINE AND MACHINE OILS

Suitable grades for every class of lubricating service. The extraordinary lubricating properties of these oils, combined with zero cold test, allow one oil to be used for a great range of work. Oils that are exactly suited for the lubrication of

HIGH AND LOW SPEED ENGINES

Light and Heavy Machines
Dynamos and Motors
Horizontal and Vertical Turbines
All makes of Ice Machines
All designs of Spindles
Every character of Loom or Knitting Machines
Milk and Cream Separators
Air Compressor Cylinders
Pneumatic Tools
Heavy and Light Crusher Rolls
Cold and Hot Calender Rolls
Oils for Farm Machinery

NOW
TEXACO
TRANSMISSION LUBRICANT
THE TEXAS COMPANY
TEXACO
THE TEXAS COMPANY
UNIFORM QUALITY
PORT ARTHUR
TEXACO MOTOR OIL

TEXACO GAS ENGINE OILS

The highest grade of mineral oils for the lubrication of internal combustion engines. In all cases especially constructed to meet the peculiar requirements of

GAS AND GASOLINE ENGINES

Producer Gas Engines
Blast Furnace Gas Engines
Coke Oven Gas Engines
Natural Gas Engines
Illuminating Gas Engines
Oil Engines Marine Motors
Automobiles, etc.

TEXACO RAILWAY OILS

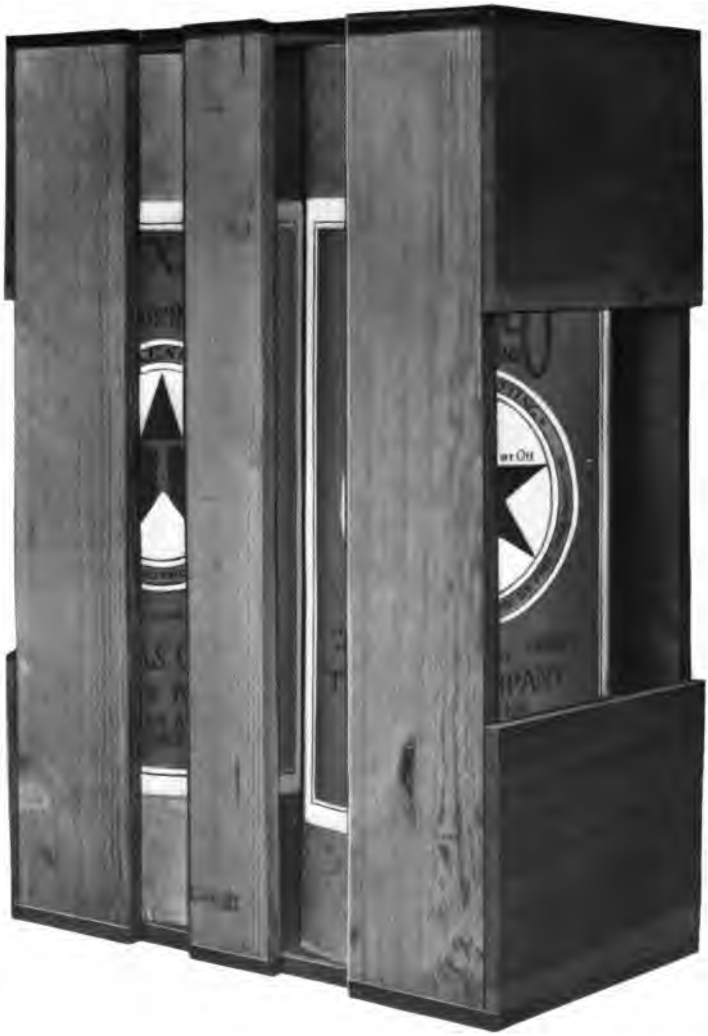
FOR

Valve Lubrication
Compressor Lubrication
Motor Lubrication
Engine Lubrication
Car Lubrication

TEXACO MARINE OILS

FOR

Cylinders Reciprocating Engines
Forced Feed Engines Turbines
Motors Ice Machines



Texaco Roofing packed for export

TEXACO SPECIAL OILS

FOR

Electric Transformers
For Concrete Forms
Hydraulic Systems
Rubbing Oil
Wool Stock
Liquid Floor Dressing
For Leather Manufacturers
For Dipping
Miners Burning Oil
Brick Oil
Thread Cutting Oil
Ink Stocks
Cordage Oil
Belt Dressings
Twine Oil
Axle Lubricants
Tempering Oil
Harness Oil

TEXACO BLACK OILS

Summer Black Oil
Winter Black Oil

TEXACO GREASES

A suitable grade for all bearings where greases can be used to advantage. Our line consisting of

Cup Greases of all consistencies
Auto Grease
Curve Grease
Transmission Grease
Skid Grease
Driving Journal Compound
Mill Grease
Chain Grease
Crank Pin Grease
Rope Grease
Coach Grease
Pinion Grease
Axle Grease
Wire Grease
Car Grease
Gear Grease

SPECIALTIES, SUCH AS

Storm Oil
Hull Coating
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